



REPORT OF SURVEY CONDUCTED AT

**ELECTRIC BOAT CORPORATION,
QUONSET POINT FACILITY
NORTH KINGSTOWN, RI**

JULY 2003



Best Manufacturing Practices

1998 Award Winner



INNOVATIONS IN AMERICAN GOVERNMENT

BEST MANUFACTURING PRACTICES CENTER OF EXCELLENCE
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Foreword



This report was produced by the Office of Naval Research's Best Manufacturing Practices (BMP) Program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective toward this goal is simple: to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP Program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management—all areas which are highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource in helping companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to learn from others' attempts and to avoid costly and time-consuming duplication.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at Electric Boat Corporation, Quonset Point Facility, North Kingstown, Rhode Island conducted during the week of July 21, 2003. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from industry, government, and academia throughout the U.S. and Canada – *so the knowledge can be shared*. BMP also distributes this information through several interactive services which include CD-ROMs and a World Wide Web Home Page located on the Internet at <http://www.bmpcoe.org>. The actual exchange of detailed data is between companies at their discretion.

Electric Boat Corporation, Quonset Point Facility is recognized throughout the country as an innovator in submarine technology and development. The company demonstrated its experience, technical expertise, innovation, and motivation, clearly indicating that continuous process improvements, the environment, its workforce, and success are part of its culture. Among the best examples were Electric Boat Corporation, Quonset Point Facility's Pipe Producibility Validation Process, Electronic Work Packages, Laser Marking of Plates, Energy Management System, Continuous Improvement Program, Safety Recognition Program, and implementation of Lean manufacturing practices.

The BMP Program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on Electric Boat Corporation, Quonset Point Facility expand BMP's contribution toward its goal of a stronger, more competitive, globally-minded, and environmentally-conscious American industrial program.

I encourage your participation and use of this unique resource.

A handwritten signature in black ink that reads "Anne Marie T. SuPrise".

Anne Marie T. SuPrise, Ph.D.
Director
Best Manufacturing Practices

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Section 1

Report Summary

Background

Electric Boat Company was established in 1899 to implement submarine designs by John Phillip Holland, an Irish schoolteacher, dreamer, engineer, and single-minded genius whose love of the sea and superior talents for machine design made him the architect of the modern submarine that has revolutionized naval warfare. On November 23, 1973, Electric Boat opened its Quonset Point Facility (EBQP) in North Kingstown, Rhode Island, on Narragansett Bay. The 169-acre facility has access to water, air, rail, and interstate highway systems. Here, major submarine components and hull cylinders are cut, machined, and formed using digitally controlled machines. This precision process is driven by the electronically transmitted digital design data from the design team at Electric Boat's Groton, Connecticut Facility. The completed submarine hull cylinders are outfitted with tanks, propulsion and auxiliary machinery, cruise missile and torpedo tubes, piping, wiring, and lighting, and are then barged to Groton or Northrop Grumman at Newport News, Virginia, for completion.

EBQP hosted its first BMP survey in March 1999. The survey focused on Quonset Point's unique fabrication capabilities to manufacture submarine hull cylinders and major components using digitally controlled machines. The survey team documented such best practices as the company's employees' assistance program, process improvement program, safety quality action team and safety action reviews, cost-of-quality program, off-hull outfitting, automated frame and cylinder system, and barging from Quonset Point to Groton.

EBQP enthusiastically hosted its second BMP survey during the week of July 21, 2003, with the entire facility becoming involved. The company once again demonstrated its experience, technical expertise, innovation, and motivation, clearly indicating that continuous process improvements, the environment, its workforce, and success are part of its culture. EBQP focuses not only on its manufacturing

processes, but on the health, safety, and development of its employees as well. It has aggressively enhanced training and education programs, encouraged employee involvement in leadership and communication, and improved safety and health programs. EBQP has implemented advanced manufacturing resource planning, installed advanced manufacturing techniques, executed a comprehensive quality improvement program, and modular design and construction, which enables end-loading of its submarines. This is exemplified by the construction of the Virginia Class Attack Submarine, *U.S.S. Virginia* (SSN-774), the first major warship designed entirely by computer.

Electric Boat has been a vanguard of submarine technological development with its establishment of a standard of excellence in the design and construction of submarines for the U.S. Navy. It provided the Navy with its first welded submarine, *U.S.S. Cuttlefish* (SS-171), the first nuclear powered submarine, *U.S.S. Nautilus* (SSN-571), and the first fleet ballistic missile submarine, *U.S.S. George Washington*. EBQP's innovation, technical expertise, implementation of Lean manufacturing practices, and continuous improvement program have equipped the U.S. Navy with a submarine force that is second to none. The BMP survey team considers the practices in this report to be among the best in industry and government.

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Section 2

Best Practices

Design

Pipe Producibility Validation Process

Electric Boat Corporation, Quonset Point Facility developed a Pipe Producibility Validation process that enables the migration from a manual, labor-intensive operation to a streamlined, automatic operation. This process allows the integration of all design, fabrication, and assembly processes in pipe production, and exemplifies the company's Design / Build philosophy.

In the past, Electric Boat Corporation, Quonset Point Facility's (EBQP's) piping information was created using hand calculations based on a designer's interpretation of a hard-copy drawing. In the 1970s, EBQP began purchasing and upgrading commercial software in an effort to maintain pace with expanding batch processing and manual data input to Graphical User Interfaces (GUIs) and more powerful processing capabilities. However, this process had its limitations. The training of new personnel was difficult, automated business and design rules did not exist, and the process was time consuming and prone to error because controls on the process were manual and depended on hand calculations of individuals. EBQP's solution was to gradually enhance the process to provide:

- Graphical pipe detail and assembly sheets
- Automated work scheduling and man hour predictions
- Electronic design rule checks and man hour predictions
- Hanger and boss locations/boss drill size
- Automatically generated Direct Numerical Control (DNC) marker/cutter and bending machine instructions
- Teaming support with Newport News Shipbuilding (NNS)
- Seamless CATIA integration
- Operations analyst interface/shop floor distribution system
- Customized CATIA configuration data manager

EBQP's enhancements to the pipe producibility validation process have enabled the company to electronically complete all pipe interference checks, calculate radial growth compensation, generate all marking, cutting, and bending instructions, and create pipe detail sheets and DNC programs for the cutting and bending machines. This process also automatically checks the design rules for the distance between bends, minimum straight distance, valid bend radius, welding checks, and detail structure content check. The operations analyst is the manufacturing interface for this information and schedules the work throughout the facility. Configuration management and consistent work papers simplify shop floor processing.

Powder Paint

Electric Boat Corporation, Quonset Point Facility utilizes a powder paint process to eliminate the long process time associated with liquid paint's drying cycle time and coverage properties. This process has reduced the cycle time of painting small and large parts as much as 98%.

With the success of its automated powder coat system, implemented in 1994, for hangers, sound damp plates, and small parts, Electric Boat Corporation, Quonset Point Facility (EBQP) decided that developing a more ambitious system to handle larger parts would have merit. In 1996, EBQP responded to an urgent request from the Groton shipyard to apply 10 to 20 mils of epoxy powder to two, 750-pound torpedo tube doors using a makeshift set-up of existing powder coat application equipment and portable heaters. Both doors were degreased, abrasive blasted, coated, cured and shipped back for installation on the ship within 10 hours. Application and curing of the traditional liquid epoxy paint to these doors would have taken four days. The success and lessons learned from powder coating these doors prompted an investigation of a powder coating facility that could handle larger and heavier assemblies.

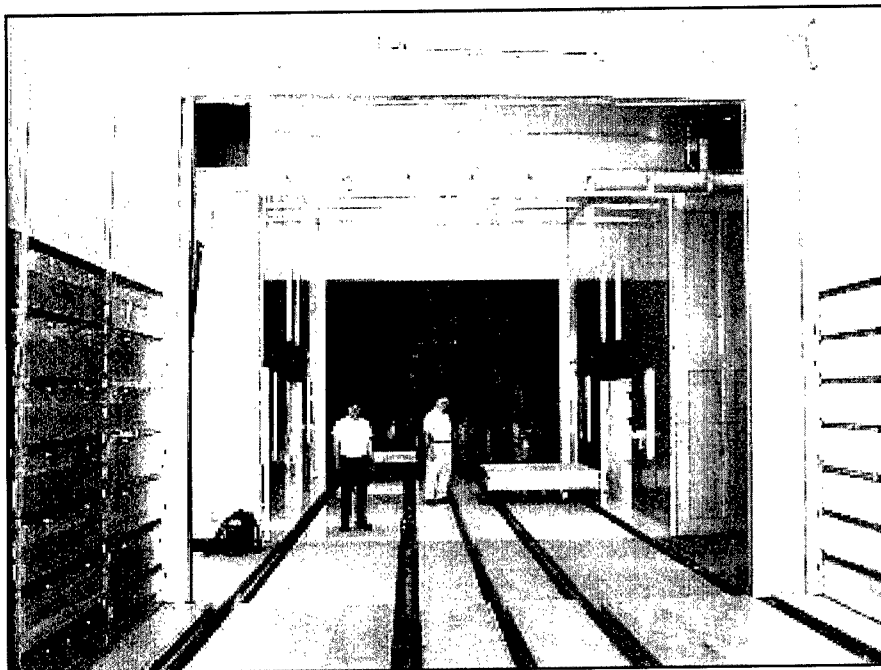


Figure 2-1. Powder Coat Facility

The ensuing investigation determined the size, weight, and the number of assemblies for powder coating. From this investigation and meetings with consultants on paint finishing process systems, the size and capacity requirements for the new powder coating facility were established. Construction on the new facility began early 2001, and opened for production in September of that year.

The Powder Coat Facility (Figure 2-1) consists of a large batch-type oven, a powder coat booth, computer controls, and two powered rail carts to move parts between the oven and the powder booth. The system accommodates parts weighing up to 40,000 pounds with a maximum size of 14' wide x 20' long x 12' feet high. The oven heats the parts to 450° F, and the temperature is monitored and controlled by a computer through a series of thermocouples attached to the part. The operator programs recipes into the computer to control the part temperature and length of time the part is at that temperature to ensure proper curing of the paint. The powder booth supports the use of four manually-operated powder spray guns at a time and also allows changes in powder colors.

EBQP powder coats more than 2,000 parts a year. The process time for powder coating parts can be up to 98% faster than liquid painting, and the total labor, material, and operating costs are typically 50% less. The significant decrease in process time

is not only obtained using powder paint, but also EBQP's innovative method of mounting and transporting the parts allowing total coating coverage without flipping or handling the part while it is at high temperature. Pre-heating the parts allows a thicker coat than a typical single coat, enabling the assemblies to be returned to the trades sooner, thereby accelerating fabrication schedules. At the same time, the quality of the coating is greatly improved because powder coating is harder and more durable than liquid coatings.

EBQP's use of powder coating is also helping improve the environment by reducing the amount of Volatile Organic Compounds (VOCs) released

into the atmosphere by 3,400 pounds a year. Unlike liquid paint, powder coatings contain no VOCs, eliminating noxious emissions. In 2001, EBQP was awarded the Governor's Award for Outstanding Achievement in Pollution Prevention in recognition of its powder coating facility for large submarine parts.

Production

Automated Frame and Cylinder System

Electric Boat Corporation, Quonset Point Facility spent considerable time and effort in staging areas for welding and outfitting operations in submarines. To improve overall quality and ease of operations, the company moved from a "stack and wrap" approach to an Automated Frame and Cylinder System.

A key element in building high quality, cost-effective submarines is the fabrication and assembly of pressure hull frames and cylinders. Electric Boat Corporation, Quonset Point Facility (EBQP) previously spent considerable time and effort in staging areas for welding and outfitting operations. Each assembly required custom spider fixtures, temporary attachments, spacers, and numerous hydraulic jacks. If any operation required turning a com-

ponent, a 10- to 15-person rigging crew was needed. Safety was a problem, and the time required to fit was lengthy. To improve overall quality and ease of operations, EBQP moved to an Automated Frame and Cylinder (AFC) System shown in Figure 2-2.

The AFC System is a series of fixtures enabling repeatable, easily configurable, and reachable frame and hull cylinder fabrication and frame-to-hull pairings for cylinders 32' to 40' in diameter. The fixtures hold the hull's circularity and rotate entire hull sections to position the sections for ease of welding and finishing operations. Several of the fixtures can elevate and rotate 180° allowing second-side welding. All fixtures have lights, pre-heaters, power, elevators, and work platforms. Partially automated welding equipment is part of the AFC System.

The resultant circularity accuracy of the hull cylinder and frame was substantially better and easier to maintain during welding operations. Total fabrication time decreased from 20,000 hours to 1,400 hours, an order of magnitude reduction. Every operation had an order of magnitude decrease in time to fabricate an assembly. The frame fabrication time decreased from 3,000 hours to 250 hours, hull fabrication from 4,000 hours to 279, hull-to-frame assembly from 8,000 hours to 459, and pairing the

cylinders from more than 6,000 hours to 528. In the recent Virginia Class of boats, process improvement continues and has decreased total cost more than 25% in the first three boats.

Clad Welding with Hot Wire Automatic Gas Tungsten Arc Process

Electric Boat Corporation, Quonset Point Facility achieved a weld wire deposition rate comparable to traditional processes by using the Hot Wire Automatic Gas Tungsten Arc Welding Process. This process produces defective-free parts, eliminating recurrent man-hours of weld repair. Cost savings associated with the Hot Wire Automatic Gas Tungsten Arc Welding Process prompted the company to review all items requiring clad welding to determine if they also could be welded using this process.

Electric Boat Corporation, Quonset Point Facility (EQBP) utilizes clad welding for corrosion resistance, surface hardening, and wear and abrasion resistance. The standard method for clad welding was the use of the submerged and pulse arc processes to achieve a high weld wire deposition rate, reduce actual welding time, and increase productivity. The drawbacks

to these processes included the rejectable defects found during the final liquid penetrate Non-Destructive Testing (NDT). Most clad welded surfaces are machined after welding and subject to liquid penetrate NDT. This test is typically performed after final machining and dimensions have been achieved. Repairing these defects is difficult and can distort the part causing an out-of-tolerance condition leading to re-welding. To reduce these occurrences, EBQP explored an alternate process which would result in a defect-free NDT.

The Automatic Gas Tungsten Arc process was examined, but failed

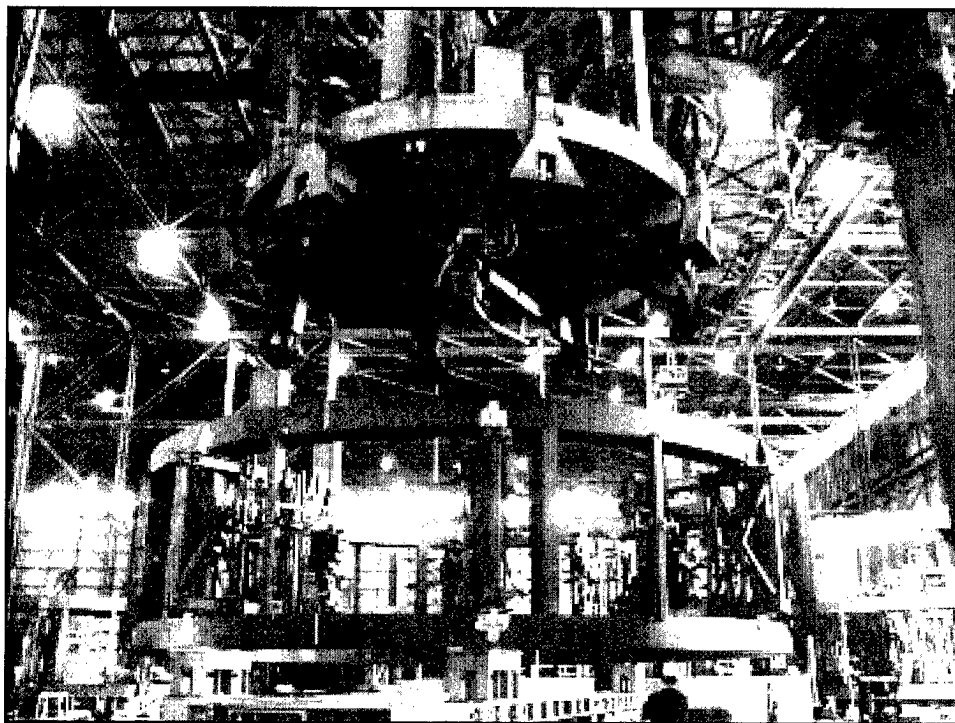


Figure 2-2. Automated Frame and Cylinder System

to produce the expected result and produced less wire deposition than traditional methods. EBQP found that by incorporating hot wire technology with the automatic gas tungsten arc process, the desired result could be achieved. The hot wire technology heats the wire as it passes through the wire feed system. This requires less amperage to puddle and deposit on the surface resulting in a wire deposition rate similar to traditional methods, but the quality of the weld results in a defect-free final machined part. To help prevent inaccessible welds, designers were given different weld tips (e.g., tungsten tip, wire feed head). This helped the design group produce weld joints with enough accessibility to successfully use the process.

Electrical Panel Manufacturing

Electric Boat Corporation, Quonset Point Facility's relocation and reconfiguration of its Electrical Manufacturing Shop facilitated the reduction in manufacturing time from 14 months to less than seven months and reduced labor costs by an average of 32%.

Electric Boat Corporation, Quonset Point Facility (EBQP) reconfigured and relocated its Electrical Manufacturing Shop using Lean Manufacturing techniques and a team of functional experts most familiar with the process. Prior to this change, the shop was remote from other manufacturing activities, mostly the Sheetmetal Shop and Test to Inspect workstations. The team performed a value stream analysis of the flow process and determined that the Electrical Manufacturing Shop should be relocated closer to the Sheetmetal Shop and the test area should be co-located in the Electrical Manufacturing Shop. In its new location, the travel distance between shops has been reduced and the coordination has improved.

The Electrical Manufacturing Shop was designed to provide optimal flow paths for console and panel manufacture, reducing travel distances by 50% to 60% for most items, and handling by 20% to 25%. It was also determined that by reconfiguring the work process into a station-loaded work cell, manufacturing times would be reduced. Materials (e.g., hardware, fasteners, and other consumables) are loaded directly into the work cell cabinets, bypassing warehousing. Delivery sites have been established for various work

cells enabling warehousemen to direct-deliver materials to the shops. Each work cell has been supplied with its own tooling, thus decentralizing the control of calibrated tools and reducing employee travel time. With few exceptions, all of the required materials and tools are at the work cell to support uninterrupted panel manufacture.

Electronic Visualization Simulation

Electric Boat Corporation, Quonset Point Facility expanded its existing Electronic Visualization System to design, plan, and digitally test new production facilities. A detailed model of the steel fabrication facility and processes is near completion and will be used by production planning to optimize and track work flow through the shop.

Electric Boat Corporation, Quonset Point Facility (EBQP) has used Electronic Visualization Simulation (EVS) since 1992 as a tool for design and production engineers. The Virginia Class submarine is the first submarine to be totally designed electronically which has facilitated greater use of EVS. The detailed visualizations generated by the EVS allow skilled trade workers to digitally build complex assemblies on the computer. This facilitates optimizing the assembly sequence, identifying potential production difficulties prior to production, and identifying design changes that could improve the assembly process and/or reduce butt welds. The trade workers can also identify ways to maximize the outfitting of assemblies during the manufacturing process, where it is easier and less costly than outfitting after the hull is complete.

The EVS significantly improved EBQP's production processes resulting in reduced costs, improved quality, and faster delivery times. Recently, the EVS was expanded to help EBQP plan, design, and test facility modernization initiatives and support production planning. The EVS now links CATIA-based product models with CATIA models of production facilities to simulate production processes by using Delmia's Discreet Event Simulation software package, Quest. This expansion provides feasibility analysis of new facilities, facility layout, material flow analysis, shop and work center planning, and demonstration of new concepts and processes to upper management and customers. The first application of this expanded system was in designing the new steel fabrication facility. It is now being

expanded to support production planning. The finished model will help production planning better sequence work through the shop, predict work completion dates, provide status of all work in the shop, provide machine utilization data, work-in-process status, impacts of additional work, and the need for additional resources and material handling requirements. It provides visualization of product flow to get all the information on any part going through the shop by pointing at the part in the visualization.

The expanded EVS system has also been used to design and digitally test a new, state-of-the-art sheet metal shop. In a continuous effort to improve processes, EBQP sees expanded uses for this new capability.

Electronic Work Packages

Electric Boat Corporation, Quonset Point Facility developed a state-of-the-art, user-friendly, Electronic Work Package system that enables planning and production managers to electronically manage all manufacturing or installation work assignments.

In the past, Electric Boat Corporation, Quonset Point Facility (EBQP) used a paper-based system for work assignments. Gathering the necessary drawings, work instructions, technical data, and status information required manually accessing multiple programs on different computer platforms using different databases. This process was time consuming, frequently inaccurate, and costly. If only a portion of a system drawing was needed for a particular job, the entire drawing and bill of material was produced from the Manufacturing Resource Planning (MRP) system.

To support the new Virginia Class submarine, EBQP streamlined its work package generation process to provide trade supervisors and mechanics timely access to manufacturing order data. To eliminate delays and improve the dispatch and flow of work, EBQP created customized work packages that provide near real-time, tailored data for current work. Dedicated employees from Quonset Point and Groton defined, developed, and deployed the requirements for an Electronic Work Package (EWP) system.

The newly developed EWP system provides the user with a seamless, familiar, Internet-style interface that easily connects to the legacy programs

and databases that contain all necessary information for work package instructions. Users can display and manipulate data for all work order requirements including data from multiple programs and databases (e.g., Manufacturing Resource Planning, Inventory Control, Shop Floor Control, Shipyard Work Status System, Controlled Pipe Joint, Material Information, References, Progress Data, Test Prerequisites, and Test Unsatisfactory Data). Users can collect, sort, and display all relevant data for the performance of assigned tasks and electronically dispatch work to the shop. If certain materials are unavailable, the system allows the electronic development of a work instruction only for the workable portion of the order. Production and planning managers now have ready access to all the information needed to optimize the dispatch and status of work.

Elimination of Seams by Maximization of 360° Forming

Through its innovative design process, Electric Boat Corporation, Quonset Point Facility saved time and materials by forming closed loop structures using only one piece of material stock, making the final product more accurate.

Electric Boat Corporation, Quonset Point Facility (EBQP) developed new tooling and techniques to manufacture heavy-walled 360° cylinders from a single piece of material. In the past, these cylinders were formed by welding together two 180° segments. The process involved prepping segment edges, making four beveled edges, welding two seams, and then inspecting the seams. The use of two segments was more expensive than one piece because of the increased labor and excess material needed on all edges to allow for pre-bending. Aligning the segments was difficult and often created excessive root gaps and circular mismatch, which led to additional welding and liberal use of tolerances to make parts acceptable.

To manufacture a part from a single piece of material, EBQP uses the 360° forming process to minimize the number of welds. The process involves manufacturing special window dies so the material can be press-formed into a cylinder. As a result, only one weld is needed to complete the part. The 360° forming process is not limited to cylindrical structures, and can be used on any closed-loop struc-

ture for which a window die can be developed. The cost savings is at least 50% based on reducing the number of welds required in half. The new method produces less rework and scrap and saves time and materials. The increased quality of the product also produces cost savings in subsequent final assembly because improved tolerances are achieved.

By maximizing the 360° forming process, EBQP improved the dimensional quality of its cylinders (e.g., improved circularity, verticality, and girths). This approach also decreased costs by eliminating extra stock for pre-bends and reducing edge preparations, fit-ups, weld joints, and weld volume.

Engine Room Raft Outfitting

Electric Boat Corporation, Quonset Point Facility's advancements in modular construction enabled the assembly of an entire engine room on an independent raft outside the confines of the main hull. With the use of digital photogrammetry, the raft can be accurately end-loaded into the hull. By assembling the raft outside of the hull with specially designed staging, schedule and labor costs have been reduced.

Historically, the main propulsion unit and propulsion plant machinery were installed on-hull in very cramped quarters. The key locating dimension for all machinery was the propulsion shaft alignment. Each component had to be landed and fitted to achieve a proper alignment. This required considerable work, and removal of equipment and staging was frequently required for each component installed. This installation sequence did not allow for flexibility, and delays in an individual component installation would cause rippling delays in the overall schedule.

Electric Boat Corporation, Quonset Point Facility's (EBQP's) design/build philosophy and advancements in modular design and construction resulted in a different approach to the shipboard loading and installation of these components. EBQP developed a customized workstation for the off-hull integration of all major engine room components into a single raft. The raft is modularly constructed in a controlled environment with readily available services, walkways, and work platforms to provide trade workers unrestricted access for outfitting. The entire raft is then end-loaded into the hull section. The modular construction allows the entire raft to be resiliently mounted as a unit rather than individually mounting a host of support equipment. The 473-ton raft is

loaded into the hull section with a tolerance of less than 3/4" while maintaining optimum shaft alignment. This is made possible with the use of digital photogrammetry which pinpoints the location of each component on the as-built unit that best suits the optimum shaft alignment.

By combining modular construction with the unique staging and the photogrammetry process, construction spans have been compressed by an estimated 42% between the first and third hulls and resulted in a reduction in labor hours by 38% between the second and third hulls. This allowed EBQP to test many of the key components in an easily accessible environment and complete the ship service turbine generator-main propulsion unit reduction gear alignment prior to landing the raft into the hull.

Fabrication and Installation of Electrical Hangers

Electric Boat Corporation, Quonset Point Facility reduced the time to fabricate and install an electrical hanger by using detailed work instructions, which are generated by a CATIA product model.

In the past, fabricating and installing electrical hangers were time-consuming tasks. Skilled trade workers were given a drawing of the cable run, and told a specific point on the run to attach the hanger. However, the exact positioning of the hanger to the overhead deck was at the discretion of the individual. As a result, highly skilled trade workers had a difficult time interpreting blueprints and identifying potential interferences (e.g., pipes, shelves, drawers) before they could fabricate and install a hanger. The process to find a location took approximately four hours per hanger. Since a submarine has thousands of hangers, this approach was very time-consuming. To resolve this situation, Electric Boat Corporation, Quonset Point Facility (EBQP) developed detailed work instructions, which simplified the fabrication and installation of electrical hangers.

EBQP uses a CATIA product model to generate the detailed work instructions. These instructions provide a precise drawing that shows the configuration and point-of-contact location for each electrical hanger. Templates are used to locate studs for the hangers, which reduce the layout time. Multiple stud locations are identified simultaneously by using a one-to-one template. Many dif-

ferent types of hangers are fabricated on the shop floor. However, the use of detailed drawings opens up other manufacturing options such as fabricating the parts in a specialized shop area or purchasing them from a vendor, and then delivering them in kit form to the assembly area.

Skilled trade workers now fabricate and install an electrical hanger in a fraction of the original time, and the precise drawings allow a less experienced trade worker to install a hanger in an average of two hours. The use of detailed instructions reduced the frequency of a rework resulting from improper installation by at least 70%. EBQP is also using this technique for other applications such as installing pipe hangers and lighting fixtures.

Handrail Fabrication

In the past, Electric Boat Corporation, Quonset Point Facility used hand-held vibratory machinery to make the notches for handrail assembly, a method that took many hours to complete. The process was redesigned, utilizing a dedicated work cell and a new automatic notching machine for the manufacture of handrails. This resulted in substantial labor savings and quality improvements.

In the past, Electric Boat Corporation, Quonset Point Facility (EBQP) used a standard workbench with a variety of tools to fabricate more than 500 handrails used on nuclear submarines. A time-consuming task, the mechanic would inventory a package of bent pipe to ensure that it was bent correctly before a template could be made for the notch locations. Mechanics were required to use hand-held grinders and cutters for one to one-and-one half hours for each straight cut on standard 1.90" pipe for handrails, and more time on the angle cut. This caused user fatigue, cut uniformity varied widely, and symmetry could never be obtained on

pipe ends. Hand-held tools left gaps on the cut surface of the notches making fit-up for welding challenging. Because welding on the rails was performed elsewhere at EBQP, cycle time was high as handrails traveled between departments.

In March 2003, a process improvement was initiated for handrail fabrication. A search for a semi-automated tube and pipe notcher was conducted by EBQP personnel. The company chose the RMD Machine (Figure 2-3), which is compact, user-friendly, flexible, and operates on 110 volt power supply. The operator can adjust the angle of intersection from 30° to 90° and use the cam motor that rotates a cylindrical cutting tool to make contoured notches in pipes from a one-inch to a three-inch outside diameter. The operator then simply rotates a wheel to drive the pipe into the cutting tool until an indicator tells him to stop. The entire cutting process takes less than one minute, a vast improvement over the workbench configuration. In addition, EBQP created a dedicated work cell for the handrail operation. The handrail mechanics designed their own work tables that enabled them to freely walk around the table and clamp assemblies down to the surface during fit-up and welding. The dedicated work cell also includes overhead crane service and a welding machine.

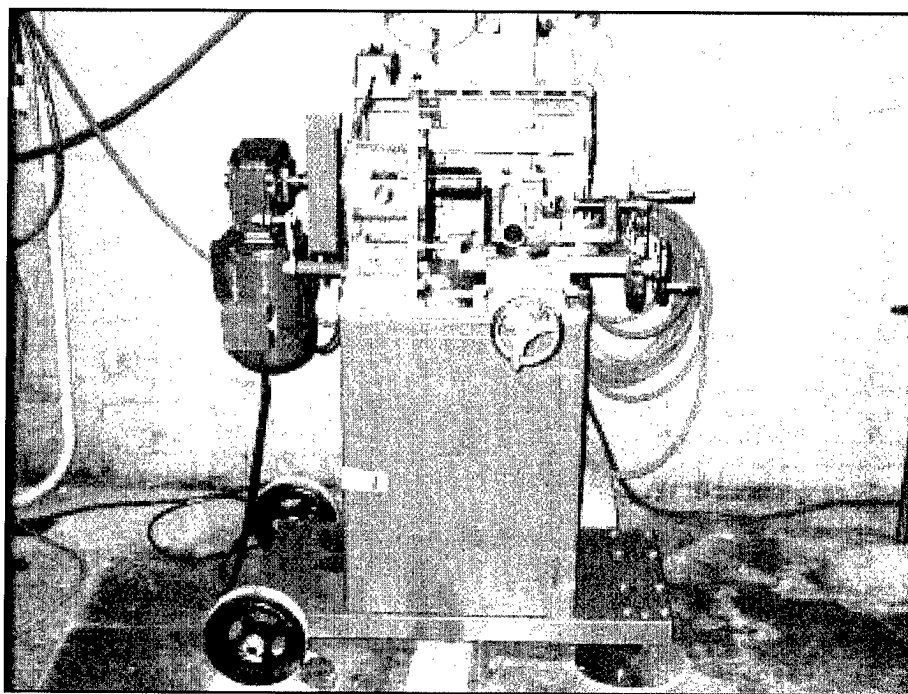


Figure 2-3. Pipe Notcher

Currently, EBQP is in the process of certifying the handrail mechanics so that one person can complete handrail layout, notching, fit-up, tack welding while the assembly is flat, and final welding of assemblies in one location. This will eliminate the need for three mechanics previously required, and reduce the unnecessary down-time for trips to welding and the tool crib. EBQP's new approach to handrail fabrication significantly increases safety and reduces vibration-related injury. Quality is vastly improved, scrap is nearly eliminated, and products are produced ahead of schedule. The cost of handrails has been reduced by at least 50%, as labor time has been dramatically slashed.

Implementation of Cold Form in Lieu of Hot Form

Electric Boat Corporation Quonset Point Facility realized considerable reduction in cost and schedule and an increase in quality by replacing a costly and time-consuming hot press technique with a cold form technique to produce complex sheet and plate metal parts.

Hot forming techniques are an expensive and cumbersome process to manufacture sheet and plate metal parts with complex curved surfaces. Each

part requires a set of one-of-a-kind forming dies (male and female) to represent its configuration. To form the part, the material undergoes a series of heating and pressing steps in the dies until the final shape is achieved. If the heating exceeds the material's temperature parameters, then its properties will be breached and it will require annealing, tempering, or possibly replacement. In many cases, Electric Boat Corporation, Quonset Point Facility (EBQP) had to enlist outside vendors to manufacture its complex metal parts using these techniques, which added additional expense.

Searching for a more economical and faster way to produce these parts, along with a diminishing number of available vendors, EBQP developed in-house cold forming techniques using existing equipment. EBQP developed multi-purpose dies, which can be readily made in-house at a fraction of the cost of hot forming dies (Figure 2-4 shows this three-part tool). The multi-purpose female die is used for a wide range of part sizes and shapes; the male die is used for parts within a specific range of radii. The operation employs a 3,000-ton Southpark press with a 50-inch press opening and a 20-foot width. To manufacture a part, the press operator gradually rotates and presses the material until the desired shape is achieved. The shape is confirmed by using radius gauges.

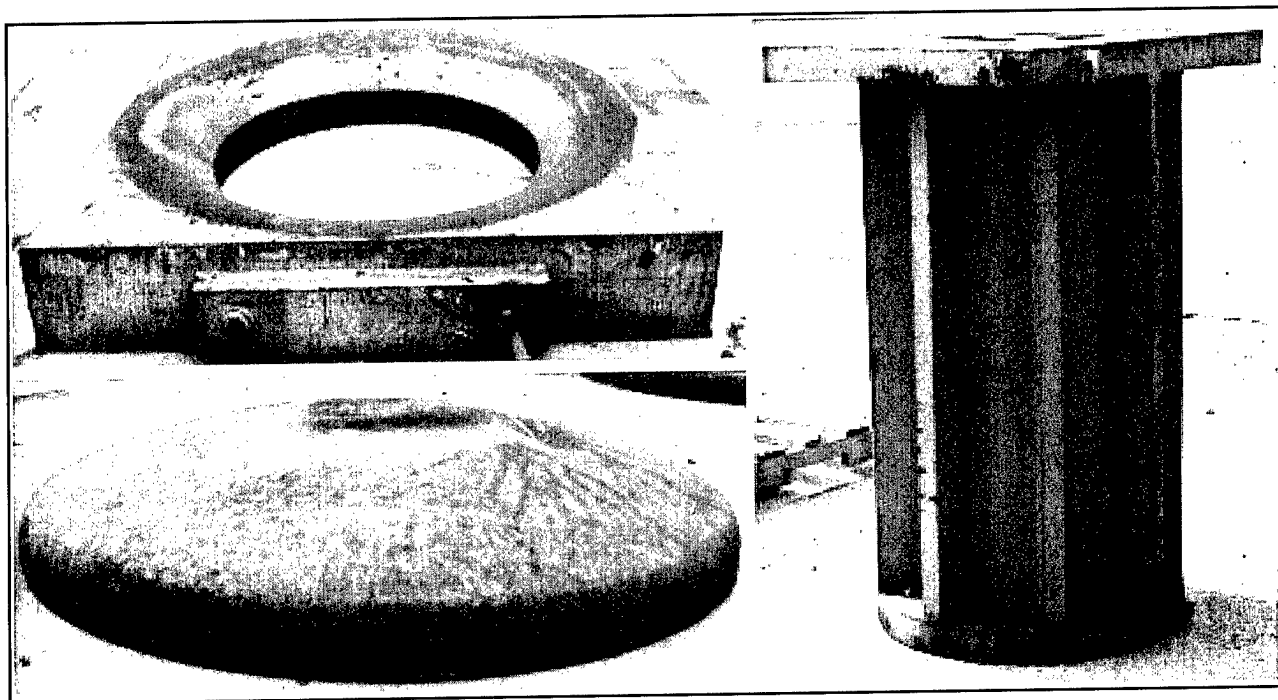


Figure 2-4. Three Parts of Multi-Purpose Dies

The cold press technique has proven so successful that EBQP uses it to produce all its complex shaped metal parts, and hot forming is no longer used at the facility. By using this new forming process, the company has improved quality and cut both time and costs of manufacturing submarine parts. These savings are realized primarily through the elimination of expensive special dies and furnaces, and the reduced number of formed surfaces with each unit. Cost savings are also realized by reducing the fabrication time for these parts. Savings have been more than \$80,000 per typical part, with more than a 60% total reduction in cost. With the new process, quality has been improved, much tighter tolerances achieved, and a reduced number of test points to find a location is now in use. Additionally, the new cold forming capabilities have been added to the CATIA design rules, so that overall producibility and quality continue to improve.

Laser Marking of Plates

Electric Boat Corporation, Quonset Point Facility recently developed an integrated process that downloads part assembly interface information from the CATIA computer model database, and laser marks plates with precise location lines for fitting pieces together, marking part numbers and interfacing part numbers, and forming and processing information.

The primary material used in submarine construction are metallic plates that are cut, bent, or formed into shapes and welded together into complex assemblies. Electric Boat Corporation, Quonset Point Facility (EBQP) recently developed an integrated process that downloads part assembly interface information from the CATIA computer model database and laser marks plates up to 50' long and 15' wide with this information. The EBQP-developed laser etching system is unique in the world and designed to the company's specific Navy requirements. Depth and lack of material damage were validated by a significant design-of-experiments approach. EBQP now laser scribes precise location lines for fitting the pieces together, marking part numbers and interfacing part numbers, forming and processing information, and delineating maximum weld boundaries for adjoined pieces. Weld information is drawn from an automatic weld process system, and the information needed for assembly by the shipfitter is etched on both sides of

any plate, if required. The marking of all layout and reference lines is accurate within a $\pm 1/32$ of an inch. The successful implementation of this complex process allowed EBQP to eliminate a manual layout, improve accuracy, minimize weld deposition, and reduce or eliminate the number of two-dimensional, paper assembly drawings required to assemble the part.

The process provides for a computer-aided, automatic marking of steel plates before they are cut from raw stock. Combining this with the detailed design database, the advanced plate processing system and the Statistical Process Control (SPC) of plates, greatly reduces processing time and labor while increasing accuracy and eliminating excess work on the shipfitter later in the process. The expensive, manual marking and layout operations currently accomplished during structural fabrication/assembly are being minimized or eliminated. Also, mechanics are not spending significant time reviewing and interpreting drawings. Planning efforts are streamlined by monitoring required work packages and providing unified kits in the proper sequence. This automated, streamlined process provides a product that is more affordable to build and has significant reductions in manufacturing lead times. Benefits of this process, as integrated with the advanced plate processing system, the computer model database, and the SPC process, include an overall reduction of 47% in per-part labor hours and 26% reduction in structural fabrication labor hours downstream.

Maintaining Dimensional Control of Parts Using Super Piece Process

Because of material purchasing limitations or different plate materials or thickness, super piece parts consist of many different plate sections that are welded together. Electric Boat Corporation, Quonset Point Facility's Super Piece process optimizes the fit-up process, minimizes root gap to ensure weld quality, and minimizes the effects of tolerance stack-up and weld shrinkage on the over-all dimensional accuracy.

Some plate parts are created by fabricating many small plates and assembling them in a piece-meal fashion into super pieces. In the past, individual small plates were cut to size and formed with edge preparations prior to assembly. Irregular fit-ups

typically occurred due to tolerance stack-ups, material mismatch, and weld shrinkage which reduced the end-item dimensional accuracy. In particular, weld root gaps were not consistent and made defect-free welding a difficult task. Shrinkage from each weld also caused distortion in the part allowing the welding process to contribute to inaccuracies. This was exacerbated by irregular weld root gaps which cause uneven heating along the weld line. Electric Boat Corporation, Quonset Point Facility (EBQP) resolved these problems by initiating a Super Piece process, in which several pieces are combined to make one large part.

The Super Piece process enables EBQP to create a part with better weld acceptance that meets tight dimensional tolerances. Edge preparations for parts now exist only on the edges that make up the welded seams of the assembly, and the fabrication of each individual piece is optimized around the welded seams with extra stock in areas that are not welded. This allows the welder to fit the pieces in a manner that ensures a quality weld. After the pieces have been welded into the super piece, reference lines are marked for final trimming.

The Super Piece process enables EBQP to minimize the impacts of irregular fit-ups due to tolerance stack-up, material mismatch, and weld shrink-

age, and improves the overall dimensional accuracy of parts. Since the majority of the welding processes are now performed in the flat configuration with the parts fit-up to optimize welding processes, the quality of the weld joints has also improved. EBQP can produce a final assembly configuration within 1/8 inch of the nominal drawing requirements on large-scale submarine components.

Modular Constructed Command and Control Center

Electric Boat Corporation, Quonset Point Facility streamlined the construction, outfitting, and test processes of its Command and Control System Module by using modular construction, thereby reducing overall submarine construction time.

Electric Boat Corporation, Quonset Point Facility (EBQP) traditionally constructed the command and control center in a fragmented way. The installation of wiring, including connector work, was system driven and completed after the various system components and stand-alone mockups were in place in the final ship's position. Substantial coordination was required to avoid schedule disruption.

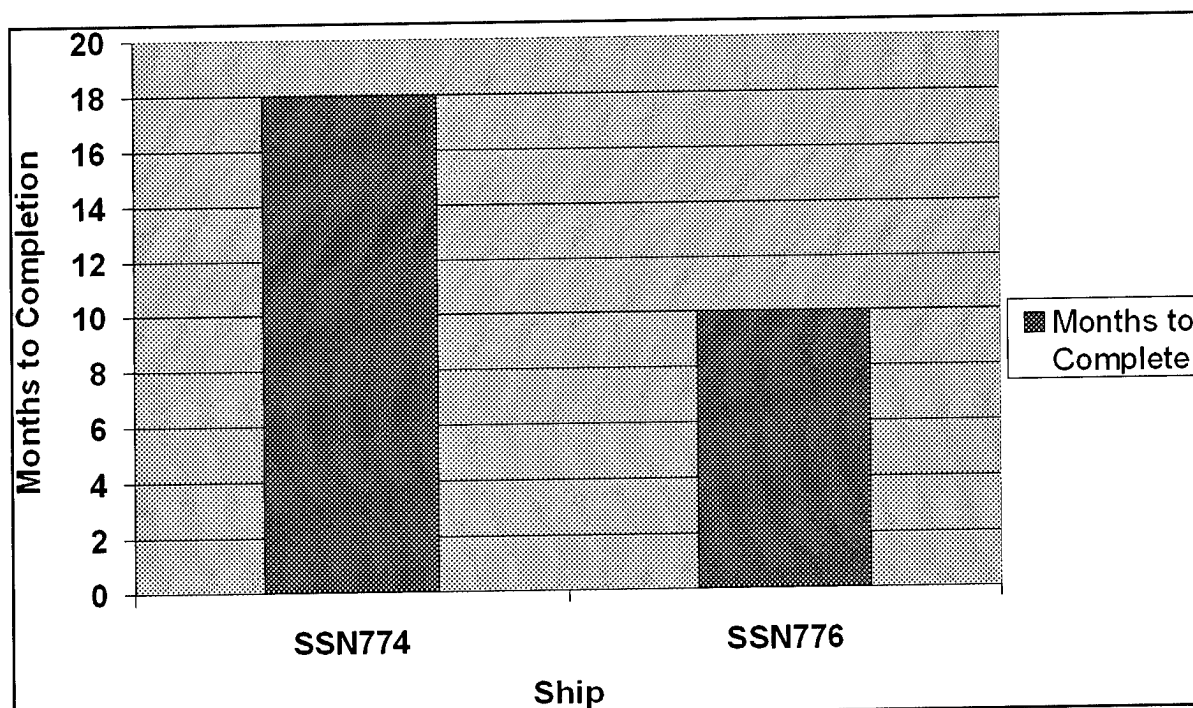


Figure 2-5. CCSM Construction Cycle

These installations were performed on-hull, with limited access and in confined work spaces. Some previously installed components had to be removed for access which caused schedule slippage and increased cost. Testing was performed after installation into the hull, causing major problems when rework was required. The move to a modular construction method greatly reduced these issues, and was the beginning of a new process that is continually being refined. A 5S approach is used to sort, set in order, shine, standardize, and sustain.

The Virginia Class Command and Control System Module (CCSM) is an example of the new modular submarine construction. The process began with the design of a self-contained deck module to house all of the electronic packages and associated equipment that encompass the submarine's command and control center. The module is constructed and tested before it is inserted into the hull, opening up workspace so many functions can be performed in parallel. Most recently, a process improvement team at EBQP redesigned their work area to support multi-ship construction of these modules to significantly improve process flow.

The results of the team's efforts include an environmentally controlled integrated station for manipulation of electrical cables; a small, on-site electrical assembly area; a tool room; an office for supervisors; employee lockers; and deck-level service platforms. Support services and unobstructed personnel access are provided at every level. An optimum environment is created for outfitting the module and performing the intricate wiring of electronic components. The centralization of tooling, personnel, and supervision greatly reduced the cycle time by eliminating time-consuming tool and equipment retrieval and easing employees' personal requirements. Figure 2-5 shows the benefit of continuous improvement from the first modular construction to the next, which was completed eight months earlier than the first.

Modular Design, Construction and End Loading

Electric Boat Corporation, Quonset Point Facility implemented modular design and construction to enable the end-loading of submarines. End-loading construction processes develop hulls with better circular geometry and stability than those built by traditional bottom-up methods.

Electric Boat Corporation, Quonset Point Facility (EBQP) implemented modular construction to enable the end-loading of submarines. End-loading construction processes develop hulls with better circular geometry and stability (both critical features in a submarine) than those built by bottom-up traditional methods. For years, EBQP increased the amount of modular construction within its overall process. The scheduling was easier, and the quality and ease of assembly and integration have substantially increased. Metrics indicated a minimum rule of 3:5:8 in cost. This means that an operation costing \$3 to perform on the shop floor at the part level, will cost \$5 to perform at the modular construction phase, and will cost \$8 to perform when done in the hull. The earlier an operation can be performed, the less expensive and easier it is to do. Modular construction allows each piece to be welded and assembled in the easiest position and configuration, with all trades working more effectively with almost no rework.

To be more effective, EBQP moved to a completely modular design on the new Virginia Class submarines, which enables modular construction. Parts, assemblies, super pieces, and the overall boat are modeled in CATIA. Detail design layouts including piping, power, mechanical, and other trades are included and optimized by modeling. Load and unload paths, including end loading, are also modeled before actual construction to optimize the layout. End loading is achieved with transporters that lift from below to move, rather than moving by overhead cranes. Units up to 400 tons can be end-loaded, and the subsequent assemblies up to 2,500 tons can be moved. The improvement in tolerances from modular design and construction has significantly eased the integration time for the overall boat to one to two weeks for everything except nuclear components. The final assembly fit within the submarine is within four inches of the hull, and the new deck designs are also independent structures from the hull, permitting quieter operation.

An additional, substantial advantage of the modular design is the flexibility it provides. While most companies automate to enable mass production, EBQP has automated to benefit a business of one-of-a-kind deliverables. Most submarines have only the hull structure and small parts which are repeatable; all other design is customized for each boat. CATIA modeling and modular design and construction principles enabled EBQP to optimize the design before actual construction and substantially streamline the integration.

Modular Unit Transportation

Electric Boat Corporation, Quonset Point Facility realized many benefits from implementing the Sea Shuttle Jack-Up Barge and the Scheuerle Transporters.

In 1974, Electric Boat Corporation, Quonset Point Facility (EBQP) began fabricating small unit packages (e.g., tanks, pipe packages, electrical components) for submarines and shipping them to the Electric Boat facility in Groton, Connecticut for final assembly and installation. Initially, EBQP shipped the packages by truck or small barge. EBQP began manufacturing internal submarine components as well as larger units (e.g., hull cylinders, decks) when the need to reduce manufacturing costs and relieve congestion at the Groton shipyard, where space and manpower were limited, was realized. These issues were addressed when EBQP planned to further expand its scope of work by outfitting the hull sections with internal structures and hardware prior to shipping them. However, EBQP's existing crane and barge capabilities (300 metric tons) were insufficient to handle the weight of outfitted hull sections.

In the early 1980s, Electric Boat Corporation (EBC) acquired a Sea Shuttle Jack-Up Barge, as shown in Figure 2-6, and modified its Quonset Point

and Groton facilities for compatibility. This 75' x 195' barge has a dead weight capacity of 2,200 tons and features drive-on capabilities for loading and unloading. To stabilize itself, the barge extends its three legs into the water and onto a concrete pad at the dock. The legs also lift the barge out of the water until the deck is level with the dock. In conjunction with the barge, EBC purchased two Scheuerle Transporters (Figure 2-7), each with a 790-ton capacity for drive-on capabilities. These transporters can also be used in tandem to move up to 1,580 tons onto the barge.

EBQP teamed with Newport News Shipbuilding (NNS) to jointly build the Virginia Class new attack submarines. Under this arrangement, each shipyard takes the lead on constructing certain sections of the submarine, with both facilities sharing the final assembly responsibilities. Since large sections will need to be shipped between their sites, EBQP and NNS developed a transportation plan based on EBC's technique for shipping from Quonset Point to the Groton facility. To implement this plan, NNS constructed a docking facility, and EBQP upgraded the Sea Shuttle Jack-Up barge to U.S. Coast Guard standards for open ocean use.

EBQP realized many benefits from implementing the Sea Shuttle Jack-Up Barge and the Scheuerle Transporters. Since the mid-1970s, the

company has increased its weight capacities to support new construction requirements. An increase from about 300 tons to 3,000 tons for barge shipping and transporter movement has been developed during this period. Loading and unloading procedures have been simplified, and the number of trips made by the barge was reduced. By being able to transport outfitted hull sections to another site, EBQP also shortened its production cycle and realized significant cost savings. The ability to outfit hull sections prior to assembly is a major benefit, due to reduced expenses compared to the cost of on-ship outfitting.

EBQP is continuously improving module transportation, which is based on their lessons-

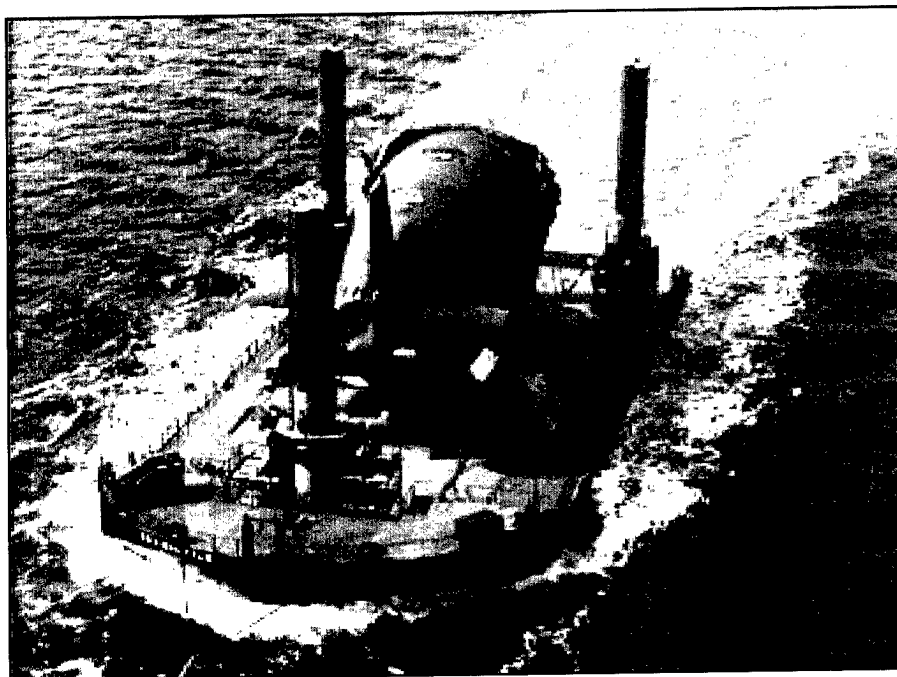


Figure 2-6. Sea Shuttle Jack-up Barge

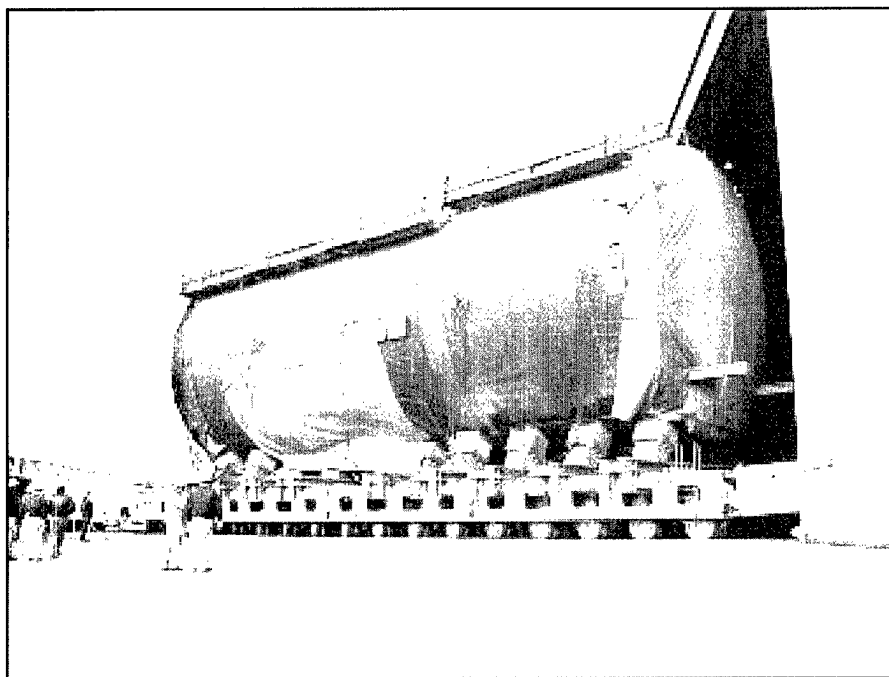


Figure 2-7. Scheuerle Transporter

learned program. The company developed an environmental enclosure for shipping weather sensitive modules across the open ocean. EBQP and the Groton facility are currently using computer simulation to study module movements.

Modular Work Platforms for Vertical Outfitting

As the result of group participation and brainstorming, Electric Boat Corporation, Quonset Point Facility designed and installed a new, modular, free-standing, highly-configurable platform for vertical hull outfitting. This resulted in a decrease in platform set-up time, an increase in safety, and a significant reduction in hull outfitting time.

The start of submarine cylinder outfitting begins with hull units in the vertical position, and easy access to every part of the unit. This is a major requirement for the success of the installation trades efforts. Electric Boat Corporation, Quonset Point Facility's (EBQP's) previous staging process was labor intensive. It consisted of attaching frame brackets, planks, plywood, and handrail supports onto the hull structure itself at various levels, a process that was very time consuming. The result was a constricted work space with serious space limitations

for tools and equipment. Additionally, the staging had to be removed and replaced or shifted during the installation of major internal components, which added to labor costs. Utilities such as power cords, welding leads, and air and gas hoses became a cumbersome maze that inhibited good work habits and safety.

To improve this process, EBQP designed and deployed modular, reusable work platforms, which are constructed from unique, custom-manufactured staging components designed with CATIA models of the hulls. Although its components are easily erected or removed from the submarine hull section, when the section is axis-vertical, the modular work

platform allows complete access to all the internal areas of the hull, and provides all the necessary supporting services and a safer working environment. Although these innovative structures were only recently deployed, early results indicate they will cause less work disruption and require less labor to erect and maintain than conventional stage building.

EBQP's new process is the result of combined team brainstorming and consists of portable, self-contained, freestanding work platforms, which can be set-up rapidly and stacked at requisite levels using overhead cranes. The 7'6" platform height allows required head clearance after the installation of lighting fixtures. Utilities are kept organized by common access with built-in, in-line controls on every level. The decking and deck support arms are adjustable and/or removable to allow easy access for working on and installing the hull components. The adjustable platforms accommodate the loading of tanks, foundations, piping, and ventilation packages, and the completion of electrical work without extensive platform revision. With the new vertical work platform, the use of wood and its related labor has been nearly eliminated. The final step in the vertical construction is the blasting and painting of the hull unit. This new platform configuration facilitates the relocation of the unit to paint facilities, and thus supports the needs of the paint shop personnel.

The new platform methods and procedures shorten the time required to ready a unit for productive work from two weeks to two days, reduced budgeted man-hours, and compressed span times throughout the entire vertical outfitting process (37% in recent units). This process also reduced recordable injuries, increased the productivity of all trades, improved the organizational appearance, and raised the general morale of EBQP's employees.

Multi-Clamp Program

Electric Boat Corporation, Quonset Point Facility's Multi-Clamp Program team optimized existing manufacturing techniques and technologies to dramatically reduce fabrication time while improving the quality of the product.

Electric Boat Corporation, Quonset Point Facility (EBQP) identified an inefficient production process for clamp fabrication. The process involved cutting clamp forms from raw sheet stock, punching end holes, and bending using a single bending die. Although the clamps were ordered in batches of 25 to 200, the operator produced them separately. This costly, inefficient process produced inconsistent bends and sometimes resulted in scrapped or wasted material.

A process improvement team of lofting, manufacturing, and end users was established to determine a less costly, better quality process. The goal was to develop a process that would eliminate the need to shear individual strips for the clamp halves and change the method for drilling or punching bolt holes. The team developed the Multi-Clamp process that implemented a Computer Numerical Control (CNC) machine code for making either a four-bank or ten-bank clamp part. The team also manufactured dies that bend the multi-clamp banks in one bending motion. The batch processing of clamps, using a group technology system, decreased manufacturing time by 50% while improving the product's quality and reproducibility. The process eliminated steps, reduced paperwork (work orders) and material handling, and improved safety.

Optimizing Machining Set-ups

Mobile workstations proved to be a useful tool for Electric Boat Corporation, Quonset Point Facility to resolve machine set-up problems. Set-up repeat-

ability is better achieved on future hull builds due to photographs of optimum set-ups that are retained electronically and can be readily retrieved.

Machine set-up has always been a problematic process in a machine shop. It can consume a significant amount of time, set-up materials may be shared and are therefore scarce, and may not be documented causing repeatability to decrease. This was an issue for Electric Boat Corporation, Quonset Point Facility (EBQP) because of the complex set-ups that take place to machine and assemble products for a submarine. EBQP addressed this issue in the past, but initiatives to improve set-up efficiency were not sustained, set-up data was not documented, and set-up tooling costs were not justified. Because of recent successes with teaming, EBQP established a process improvement team comprised of a programmer, rigger, management representative, and an operator from each shift to address the area. A logbook was maintained for four to six months recording set-up issues that occurred. Digital photographs were taken on a weekly basis to record operations. When the team reviewed the data, EBQP recognized issues that needed to be addressed.

Because of the size and design of some of the machines, operators traveled distances of 40 feet or more to obtain necessary hardware from storage areas, and multiple trips might be required due to the complexity of the set-up operation. Machining support equipment such as vises, workbenches, and turning tables became a collection area for tooling. Ideas were discussed among the team members, and it was decided that mobile workstations would be well suited for the large complex set-up operations and machines, while more permanent workstations would suffice for smaller ones. The team addressed the mobile workstations first, and drafted several design options that resulted in four mobile workstations being built with each having a special purpose. The first was a workbench that could be mobile or stationary; the second was a clamp cart that carried varying sizes of clamps; the third was a cart for threaded rods and nuts of varying sizes and lengths; and the fourth was a cart for stacking blocks. The team also designed a more stable stacking block system by using an interlocking mechanism to provide stability in the vertical and horizontal positions. Benefits achieved include a reduction of set-up time by as much as 15%, reduction of non-value hours of travel time by operators,

new ideas being developed by a diverse process improvement team, more stable set-up through the use of interlocking stacking blocks, and improved repeatability and productivity with the use of digital photographs to capture set-up operations for use in future jobs.

Pipe Packaging for Modular Construction

In support of Electric Boat Corporation, Quonset Point Facility's modular construction manufacturing practice, the company fabricates and assembles pipe packages in temporary fixtures in its pipe shop. These packages are then transported to the submarine hull section or module for final installation. This approach improved safety and quality and decreased labor costs and span times.

Traditionally, submarine construction programs consisted of four sequential, labor-intensive phases: manufacturing; structural assembly; installation; and test. Installation of piping was accomplished after the structural assembly was completed. Pipe details fabricated within Electric Boat Corporation, Quonset Point Facility's (EBQP's) pipe shop were transported piece-by-piece to the submarine hull section as needed for installation (referred to as stick building). Problems with this approach were that the installation sequence for the components was critical, the work had to be accomplished in extremely congested areas, and general working conditions were inefficient. As a means of reducing construction time and cost, EBQP took advantage of advances in submarine designs, information technology, equipment technology, and manufacturing integration by using the design model to develop larger and more complete pipe packages. EBQP focused on moving cleaned pipes directly from fabrication workstations to manufacturing workstations where the pipes are assembled in temporary fixtures, containing two to three pipe details or banks of pipes. After completion of a pipe package, the entire fixture is then transferred to the appropriate hull section or module. Foundations are located, the hangers are welded into place, the temporary fixture is removed, and assembly is complete. EBQP's engineers determined that assembly, which requires one hour in the pipe shop, takes four hours in the unit and ten hours in a sealed hull. Thus, pipe packaging for modular construction saves labor and span time and improves safety and quality.

This process was originally implemented for the 688 and Trident Class programs. EBQP extended the lessons learned from pipe packaging and is now creating dedicated workstations for specific, repetitive packages. Currently, a material pick list is given to EBQP's material department to collect and deliver to an area selected for manufacture of that package. While the mechanic waits for material to be delivered and inventoried, specialty tooling or support equipment needed to complete the job is collected from around the shop. With recent procedural changes, each workstation now contains all the equipment, fixtures, and tooling necessary to assemble certain packages. Workstations are located in areas with suitable clearance and power supply. Pipes, valves, and related components are no longer stored in a material warehousing area, but are delivered directly to the workstation from the bending stations. Once the package is permanently fitted into its design location and the temporary fixture is removed, the fixture is refurbished and returned to the workstation for its next use.

EBQP's pipe packaging methods emphasize quality. Using photogrammetry, mechanics establish soft targets in the shop environment to template the actual construction conditions. This process ensures that, after a critical pipe detail is manufactured, it will fit the as-built condition. Cost savings have been realized with the reduction in set-up time and the elimination of two material handling steps. First, is the movement to the staging area as pipes emerge from the cleaning facility; second is the re-issuing of material as it is picked by the material department. These improvements enable management to incorporate the mechanic's experience and learning curve into the manufacturing plan. EBQP shared this practice and advised its teaming partner, Northrop Grumman Newport News, on methods of achieving similar results.

Plate Processing Statistical Process Control Program

Electric Boat Corporation, Quonset Point Facility automated many of its part manufacture and assembly processes. The company established a Plate Processing Statistical Process Control Program that validates the accuracy of water jet, plasma and laser cut parts, and the laser marking system to reduce assembly time and cost.

Electric Boat Corporation, Quonset Point Facility (EBQP) automated many of the part manufacture and assembly processes by feeding the detail design database (based on CATIA) into an advanced Plate Processing and Laser Marking System. The Plate Processing Statistical Process Control (SPC) Program allows plate processing personnel to monitor and track trends in the plate marking and cutting processes. SPC statistics are interpreted through the use of control charting of the measurements taken daily. A test coupon is cut at the start of each shift and a sampling of parts is tested. The data indicates when the equipment needs calibration and can be used to take out-of-tolerance equipment off-line until adjustments are made. This type of control chart management allows plate processing personnel to continuously produce parts that exceed design specifications, with a plasma cutting accuracy of ± 0.033 ", a laser cutting accuracy of ± 0.005 ", an abrasive water jet cutting accuracy from ± 0.005 " to ± 0.020 " (depending on material thickness), oxy fuel cutting accuracy from ± 0.060 " to ± 0.125 " (depending on material thickness), and laser marking accuracy of ± 0.005 ".

Since the accuracy of the cutting and marking exceeds the design tolerances of the parts, EBQP can rely on its advanced automated systems, realizing overall reductions of 47% in per-part labor hours and 26% in structural fabrication labor hours downstream. Additional benefits of SPC include identifying the need for maintenance before operations are out-of-tolerance and fine-tuning the process.

Point of Execution Pipe Cleaning

Electric Boat Corporation, Quonset Point Facility's original methods to internally clean pipes were time consuming and labor intensive. The company adopted an innovative process using Goodway's Jet Cleaner Pneumatic Cleaning Gun and Foam Pellet which cleans pipes in only a few minutes.

The cleanliness of piping systems installed on U.S. Navy submarines must be indisputable, as piping services the nuclear reactor, propels the ship, and supplies potable water. Unfortunately, dirt and debris are introduced by mandrels during the bending process. Therefore, Electric Boat Corporation, Quonset Point Facility (EBQP) must clean all pipes produced in its facility based on requirements set forth in Standard Procedure 1.8.

Previously, pipes were soaked in a tank of trisodium phosphate solution that must be kept at a depth of 38" and temperatures of 170° to 180° for two hours. The pipes were then rinsed in a separate tank of deionized water maintained at temperatures of 165° to 185°. Because the local water supply did not meet standards, deionized water had to be made in-house, requiring additional equipment and labor costs and taking daily samples from both tanks for chemical analysis by a laboratory service chemist. Mechanics used rags soaked in alcohol drawn through the pipes on nylon lanyards. The rag cleaning process could only be used on pipes of smaller diameters, which was repetitive, time consuming, and difficult to complete on pipes with multiple bends. After cleaning, pipes were moved to the stove installation area in the cleaning facility. Staves are metallic insulation, secured to the

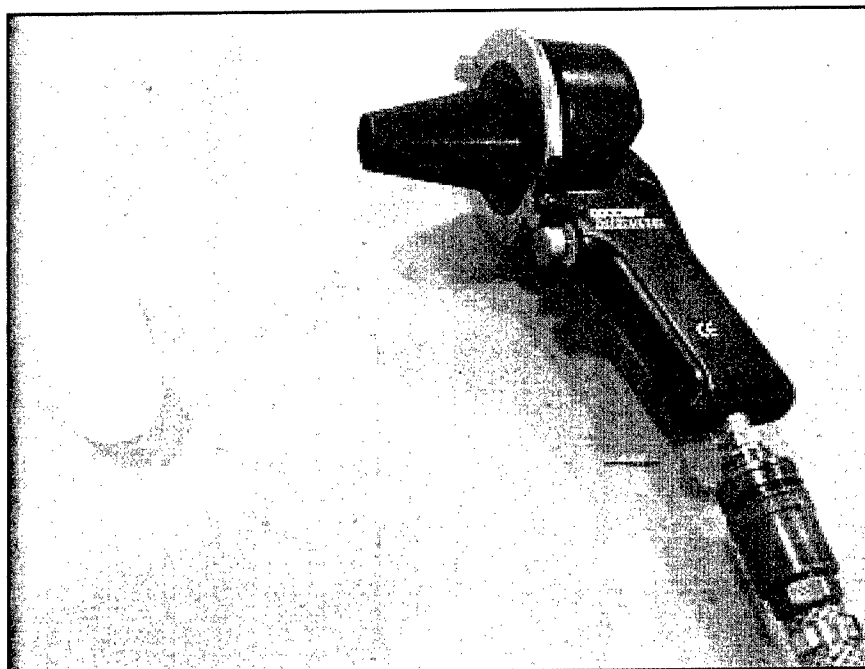


Figure 2-8. Goodway's Jet Cleaner Pneumatic Cleaning Gun and Foam Pellet

exterior of pipe to reduce noise and vibration. EBQP realized it was labor intensive and time consuming to move pipes from bending to the laundry facility staging area, to the cleaning tanks, to the stove installation area, and out of the laundry for fit-up. EBQP shifted the responsibility of keeping all materials clean from the cleaning facility mechanic to the mechanic who fabricated the piping details. This same mechanic also notified the stove installer in advance about details emerging from the bending and cleaning process, allowing the stove installation to be accomplished in the fabrication area.

In early 2002, EBQP implemented its Point of Execution Pipe Cleaning to achieve these goals. The Goodway Jet Cleaner Pneumatic Gun and cylindrical foam pellets (Figure 2-8), soaked in a cleaning solution of one part Bruelin (a mild detergent) to 10 parts water, is now used. The mechanic selects a foam pellet and head attachment for the air gun that fits the pipe detail to be cleaned. The jet cleaner is attached to an air hose and placed at the end of the pipe. The mechanic pulls the trigger and the foam pellet is shot through the pipe into a collection bag at an average of 100 psi. The pellet is shot through until the pipe meets cleanliness standards, usually no more than six times. EBQP is currently using this process for pipes up to four inches in diameter, but cannot use the method on pipes with fittings because grease fills the crevice between the fitting and the pipe. At least 70% of the pipes cleaned at EBQP meet these requirements, reducing cleaning time from two to three hours to less than five minutes per detail. While the foam pellets are expensive (a box of 25 costs approximately \$100), they can be reused in some cases. EBQP is investigating methods to wash and reuse all pellets.

EBQP is procuring enough jet cleaners to assemble on mobile carts. The carts will be stationed at the pipe bending work area, and pipe shop mechanics will be responsible for cleaning. After cleaning the pipe, the mechanic will cap and seal all pipe ends. The seal contains information on the cleaning process, including the badge number of the mechanic, and end-caps cannot be removed without breaking the seal. This ensures the integrity of the cleaning is maintained. The stove installation will also occur at the bending workstation. Pipes will be delivered directly from the bending area to the manufacturing area, by-passing the cleaning facility. EBQP estimates that this process will eliminate seven to eight handling steps, provide ergo-

nomic benefits, reduce cleaning tank costs, reduce the crane time necessary to move certain pipes, and increase safety.

Process Control Techniques for Pipe Manufacturing

Electric Boat Corporation, Quonset Point Facility solved its welded pipe manufacturing scheduling and work-in-process control problems by applying creative color-coding and labeling techniques to part travelers and work staging areas.

Tight schedules, unique configurations, and variable quality standards pose challenges for Electric Boat Corporation, Quonset Point Facility (EBQP) in tracking work-in-process within its Pipe Manufacturing Shop and ensuring that pipes are fabricated and packaged to exacting standards and schedules. Producing approximately 10,000 welded pipes annually, a number of techniques have been developed to move work through pipe manufacturing in the correct sequence, in minimal time, and with complete quality control accountability. These techniques include:

- **Color Coded Bag System:** During pipe welding, there are two types of joints (controlled and non-controlled), each with different handling and accountability requirements. Controlled joints require that certain steps be taken to ensure quality and accurate record keeping are performed for each welded pipe joint. These are monitored by EBQP's Quality Assurance (QA) personnel, require Non-Destructive Testing (NDT), and have clear traveler bags. Non-controlled joints are not monitored by QA, and are identified by the Color Coded Bag System and moved through the process faster once they are welded. By color-coding the traveler bags, EBQP personnel have a clear visual aid to determine which items can be shipped immediately. Pipes with non-controlled weld joints have red traveler bags, and pipe-only travelers have a clear bag with a large "X" on the outside. Typically, pipe-only orders are processed in a one-day cycle time. EBQP's Color Coded Bag System resulted in reducing cycle times from 17 days to 10 days (41%), reducing work-in-process, clear identification of pipes requiring QA, and clear identification of welded

pipes that require welding by a certified welder.

- **First-In-First-Out Pipe Rack System:** With hundreds of pipe details and assemblies being produced weekly (each consisting of one to nine individual pipes), tracking, scheduling, and controlling each piece through the pipe manufacturing shop is a difficult process. To solve this problem, EBQP implemented a labeled pipe rack system. Pipes are identified, cut to length, and placed on the "bend" racks labeled #1 and #2. This enables the pipe bending mechanic to hold to the first-in-first-out discipline and bend pipes of similar size with the same set-up, thus reducing bending machine changes. From the bending operation, the bent components are moved to fit-up and weld where a similar first-in-first-out technique has been implemented. Fitted and tacked pipe assemblies are placed on weld racks which are labeled by the days of the week, allowing welders to clearly see which assemblies are next in the cue for welding.
- **P2 Logbooks:** EBQP initiated P2 Logbooks to track non-controlled pipe joints which do not require QA intervention. Because EBQP had many P2 joints that leaked during hydrostatic testing, the company was unable to identify the welder who had welded the joint. The P2 Logbook enables EBQP to track pipe joints from start to finish, even if multiple welders are involved. This ensures that corrective and preventive action is taken. The P2 Logbook is also a vehicle for material identification prior to welding.

Producibility Reviews to Minimize Welding and Rework

Early success in the Producibility Review Process at Electric Boat Corporation, Quonset Point Facility added momentum to the Design / Build Program, significantly increasing manufacturing involvement in the design process.

Significant advances in Electric Boat Corporation, Quonset Point Facility's (EBQP's) Design/Build Program is evidenced by numerous Producibility Re-

view accomplishments. Collaboration between manufacturing and design engineering streamlined manufacturing processes, standardized design elements, and will support major advances in modularization as emerging manufacturing technologies are brought on-line. A manufacturing expert from EBQP has been relocated to EB Groton's design group to review or provide input on all build plans intended for EBQP. This open, two-way channel of communication between EB Groton's design and EBQP's manufacturing facilitates the staged acquisition of cutting-edge manufacturing technologies for early design enrichment.

Additionally, EBQP's manufacturing personnel review repetitive work packages to minimize welding operations and eliminate rework. The Producibility Reviews are part of EBQP's continuous effort to improve quality while reducing manufacturing costs. One example is found in revisions to the manufacture of cable pans and pipe details. Traditionally, drip pans were assembled from four separate pieces which were welded full length using tungsten inert gas. Welding was time consuming and required strong-backing to counteract distortion from the welding heat. Furthermore, pan straightening and extensive clean-up were required after welding which was a labor-intensive process. After introducing the Producibility Review process, a Sheetmetal Process Improvement Team devised a pan manufacturing process which required one piece of material, a press brake sequence, and minimal welding. This new approach significantly reduced welding time, eliminated strong-backing, and reduced clean-up time, resulting in a higher quality product with minimal distortion.

Another example is the manufacture of pipe details. When welding bosses on thin wall pipe, the pipe sags or collapses inward around the joint. When welded at or near the end of a pipe, heat input from the welding operation distorts the open end, jeopardizing the next fit-up. After a Producibility Review, a Pipe Shop Process Improvement Team designed a device that slides into the pipe under the boss and locks in place for pipe wall support during welding. Once the welding operation is complete, the adjustable device is easily removed and returned for re-use. This anti-sink device, shown in Figure 2-9, eliminates the undesirable distortion once common in the manufacture of pipe details.



Figure 2-9. Anti-Sink Device (Installed)

Re-Engineered Sound Dampening Manufacturing Process

Electric Boat Corporation, Quonset Point Facility re-engineered its process to manufacture sound dampening tiles, resulting in a reduction of labor hours.

Electric Boat Corporation, Quonset Point Facility's (EBQP's) original process for manufacturing sound dampening tiles was labor intensive. The process entailed the manufacturing of individual plates to which the sound dampening tiles would be glued. Many of the plates were custom made from templates requiring them to be cut, blasted, and individually painted. The sound dampening tiles were then manually cut to the same size as the plate to which it was glued. The glue, a two-part epoxy, was then scooped by hand from individual cans and mixed together manually, a time-consuming and messy process. The glue was then spread on the tile and plate, joined, and set down to dry. Tiles were stored around the sheetmetal shop while they dried. Each tile was marked by hand-written, etched identification, which required re-checking after painting. The two-part glue was packaged in individual, one-pound packets for shipping to other

areas where sound dampening was being installed. The entire process required 15 full-time people, often working 46 hours per week to manufacture the required sound dampening tiles.

EBQP re-engineered its process to dramatically improve efficiency. First, a self-contained workflow center was established for the manufacture of sound dampening tiles. Next, a standardized parts system was implemented which eliminated the need for custom templates. A digital glue dispenser was purchased that automatically took the two-part glue from individual containers and mixed them together eliminating the manual scooping and mixing. The machine was also designed to dispense individual packets for shipping to other areas that applied sound dampening. A paper cutter was purchased to cut the tiles to eliminate the

manual tile cutting. The old paint system was changed to a new powder painting system, and the manual identification process was changed to pre-printed labels made of stick-on plastic that could be easily removed after installation. Finally, an innovative system for drying and stacking completed plates and tiles was adopted. EBQP's new process resulted in a reduction of personnel (from 15 people to three people) needed to produce all sound dampening tiles.

Shop Floor Execution System

Electric Boat Corporation, Quonset Point Facility's Shop Floor Execution System took advantage of automation and software applications to improve efficiency, reduce material handling and inventory, eliminate labor-intensive data collection and reporting, and improve productivity.

When Electric Boat Corporation, Quonset Point Facility (EBQP) designed its automated Steel Processing Center, one of its features was the capability to shop load and track the movement of parts through the nesting and cutting process. The automated material handling system used in the new

automated Steel Processing Center utilized the latest innovations in conveyor and crane management. Prior to this automated process, EBQP manually tracked the ordering, receiving, and cutting processes for its structural parts. This labor-intensive production and tracking process resulted in excessive material movement, extensive use of forklifts and overhead cranes, and excess inventory management. EBQP's Shop Floor Execution System provides the Production Control group with material ordering capabilities, real-time status of all steel processing operations, and a daily production work order for each of the facility's workstations. The real-time information provided by the Shop Floor Execution System allows the Production Controllers to better plan the type and amount of work arriving at the Steel Processing Center. As work orders are selected for processing, they are grouped by material, thickness, and priority. The planners can sequence delivery of raw material required for each cutting machine, and as each plate proceeds through the cutting process, it is automatically tracked in the Shop Floor Execution System. Nesting configurations are developed to maximize material and machine utilization and minimize material handling.

Use of 2-D Mockups

Electric Boat Corporation, Quonset Point Facility's use of 2-D Mockups for the installation of wiring and piping before the actual equipment is available, has greatly reduced the cycle time of construction. 2-D Mockups enable early construction time and lessen the confined work space for the installation of the equipment.

Prior to the Virginia Class, Electric Boat Corporation, Quonset Point Facility (EBQP) hardwired electrical components in submarines directly into the components. The only exceptions were the communication and indication items. Late delivery of parts, coordination of hook-up with other operations and assembly, and space limitations made this installation difficult. A new Virginia Class design/build philosophy led to the connecting of components, including major controls and power units. By using 2-D Mockups to template electrical hook-ups to hardware, actual construction and subsequent technology insertions are facilitated.

Many improvements were immediately realized in the handling of the lightweight, easy-to-man-

age 2-D Mockups, in lieu of the actual electrical component. The mockups provide ease of installation within restricted work spaces of the deck packages which include many of these electrical components. The physical constraints within the confines of electrical equipment that normally exist are greatly reduced or eliminated. When attached to mockup frames, the packing of Multi-Cable Transits (MCTs) for cable entrances can be accomplished with ease because of greater accessibility. The open configuration of the mockup facilitates the use of cutting and crimping equipment, cable forming and manipulation, and other hookup-related tooling. Another advantage to using mockups is in maintaining the proper sequence of work when equipment requiring an electrical hookup is not available. The 2-D Mockup electrical hookup is connected, installed, tested, sold, and protected until the actual equipment is available for load out. Cable wire checks are performed through the mockup while still connected, reducing plug wear and potential damage to plugs through repetitive plugging and unplugging cycles. This approach eliminates expensive tactical hardware from being overly exposed to potential damage during ongoing construction operations. A 64% reduction in work effort for the control panel wiring was realized with the use of 2-D Mockups.

In the initial design/build team's concept for deck outfitting, the use of 2-D Mockups was intended for use on major components. Recognizing its potential, operations teams have expanded the original concept and now use 2-D Mockups on a number of lower-level systems.

Virtual Fitting of Complex Castings to Optimize Machining

Electric Boat Corporation, Quonset Point Facility successfully developed its CATIA, Computer Aided Design / Computer Aided Manufacturing capabilities and used photogrammetric survey data to create a highly efficient and accurate process for machining, locating, and installing complex castings onto a ship's hull. As the demand for increased modular designs and reduced delivery schedules continue to rise, the company's virtual fitting of complex castings provides a clear, competitive advantage in the rapidly changing maritime and defense industries.

In virtual fitting of complex castings, Electric Boat Corporation, Quonset Point Facility's (EBQP's) Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) Engineering merged CATIA and photogrammetric survey capabilities. Historically, casting installations were performed on a trial-and-error basis requiring two or more attempts before final fitting. Machining lines were laid out to the as-built ship's condition, castings were removed from location for final beveling after fit-up, part handling scenarios were undesirable, and optimal machine shop processing was rarely achieved. The casting location was determined with piano wire or fixturing, and hull weld build-ups were periodically required to complete an installation. This process was inaccurate, disruptive to work flow, and time consuming.

EBQP utilized its CATIA workstation capability and photogrammetric survey data to successfully resolve the casting installation dilemma. Employing CAD/CAM engineering capacity for design model overlay and manipulation, EBQP attained virtual hull fitting of complex castings prior to machining. This process was fully developed during machining and installation of the Virginia Class Weapons Shipping Trunk (WST), a large, complex casting. Photogrammetric survey data is collected during receipt and inspection of the rough casting, and is uploaded into CATIA and overlaid on the design model — an example of virtual fitting of complex castings. The photogrammetric point cloud is then virtually fit to the model, and optimal machining coordinates are rendered. This information is then used to establish physical reference lines and working points for set-up and machining, and define hull structure cuts and edge preps for welding. The results are less machining, less welding, a tighter fit of the WST casting to the ship's structure, and improved hull fairness.

Welding Preheat for Spherical Air Flask Manufacture

Electric Boat Corporation, Quonset Point Facility's use of ceramic heating pads to provide weld preheat in the manufacture of Spherical Air Flasks resulted in significant improvements. This process proved to be more reliable by eliminating costly installation, removal, and post-removal repairs associated with the previously used cal-rod heaters.

The Spherical Air Flask (SAF) is a large pressure vessel that provides storage for large volumes of compressed air used for surfacing the submarine and as emergency breathing air. Earlier designs were a one-piece, forged bottle that was susceptible to damage during installation. Current designs include a welded assembly, consisting of a cylindrical mid-body capped by hemispherical end heads with nozzles for supply and discharge of air. Foundation rings welded to the mid-body provide for attachment to the submarine's structure. The change to a welded assembly, made of high-yield steel, created the need for a reliable source of welding preheat to control mechanical properties and prevent weld cracking. Providing the necessary preheat to perform the critical welds in the manufacture of the air flasks had always been a challenge. Preheat was previously supplied by a high-voltage, AC cal-rod style conductive heater mechanically fastened to the SAF. These conductive heaters were an insulated resistive element inside a rigid metal sheath. The use of this type of heater had several negative aspects including:

- Need for manual installation and wiring
- Amount of heat applied was controlled by a manually-set on/off timer
- Conductive heaters were forced to conform to the cylindrical shape of the SAF by manual bending, causing hot spots and insulation failures which left arc strikes on the SAF body
- Limitation of the required cable for the SAF prevented maximum use of automated welding processes

After a comprehensive review, a process improvement team recommended the use of low voltage AC flexible resistive elements within a matrix of ceramic tiles held in place by a dedicated fixture. The individual ceramic matrix pads are thermostatically controlled to ensure continuity of temperature throughout the weld zone. Improvement was achieved with the elimination of manual installation of wiring. The amount of heat applied was now controlled automatically by thermocouple sensor feedback to zone controllers. The matrix now conforms to the shape of the SAF body eliminating insulation failures and resultant arc strikes. Fixturing of the matrix pads around the SAF also enables the use of automated welding processes.

Since the implementation of the new weld preheat process for air flask manufacture, set-up time has been reduced by 80%, energy costs reduced by

30%, manufacturing schedules reduced by 28%, and discrepancy reports associated with arc strikes have been eliminated.

Facilities

Advanced Plate Processing System

Electric Boat Corporation, Quonset Point Facility constructed a new facility around a highly advanced Automated Plate Processing System. This system is specifically designed to optimize material flow in conjunction with the Laser Marking System, Statistical Process Control, and CATIA data to create highly accurate parts for kitting and marking. This allows the fabrication of complex assemblies without the need for detailed 2-D fabrication drawings.

The primary material used in submarine construction is metallic plates that are cut, bent, or formed into shapes, then welded together into complex assemblies. Traditional plate processing methods are labor intensive, rely extensively on forklifts and overhead cranes, have little control of the storage of remnants, and material flow is multi-directional on the shop floor.

Electric Boat Corporation, Quonset Point Facility's (EBQP's) advanced Automated Plate Processing System produces highly accurate pieces that are kitted and marked for the fabrication of complex assemblies without the need for detailed 2-D fabrication drawings. These pieces are cut and kitted when required in the shipbuilding process, which minimizes the indefinite staging of cut pieces. This world-class facility incorporates unique processes developed by EBQP and utilizes the most advanced equipment and technologies available. Capabilities include double-sided marking, cutting, and forming of plates up to 15' wide x 50' long and range in thickness between 0.375" and 1.500". With the Virginia Class submarines being the first U.S. Navy ships fully designed electronically, EBQP designed and built a plate processing facility that optimizes material flow and takes advantage of the efficiencies of the design database. This plate processing system is also integrated with laser marking, cutting tools, and statistical process control (SPC) to produce high quality assemblies. The automatic nesting system is also used in the blasting and cutting processes to minimize waste, using only the material required.

The process begins when a plate is received from the plate yard and placed on the conveyor. The work package for the plate is scanned, which initializes the Direct Numerical Control (DNC) programs and establishes the parameters for the blasting and marking operation. The plate proceeds into an abrasive blast machine where only those areas designated by the cutting program are blasted. It is then advanced to the marking queue where alignment holes are drilled, and then forwarded to the laser marker which automatically aligns itself on the indexing holes using CATIA to transform data to mark each part. The laser marker etches on the near side of the plate and when the near side markings are completed, the system automatically turns the plate, re-indexes, and performs whatever marking operations have been specified for the far side of the plate. When all marking operations are complete, the plate is moved to the appropriate station for optimal cutting by an overhead magnetic crane for magnetic plates or a vacuum coupling crane for non-magnetic plates. A water jet, plasma, or laser cutting machine, as appropriate for the part and material, is then used to cut and bevel the part. Fumes from the cutting operation are captured by dampers under the cutter, filtered, and re-circulated into the shop without emissions. Parts are cut in a kit-type sequence and then delivered to the consuming work center. The delivered part contains all the information needed for fit-up and welding, and is completely ready for installation or assembly. Bar codes control the cutting and routing of the part in process.

All handling, marking, sequencing, scheduling, and cutting of the plate are controlled from a central control station. The process is designed to maximize automation in the material handling, as well as control the blasting, marking, and cutting of all plates. This process eliminates several independent operations by integrating them into a cutting line capable of being operated by three individuals who deliver completed kits that are marked and prepped for assembly. This process, integrated with the laser marking system, the computer model database, and SPC, results in an overall reduction of 47% in per-part labor hours and 26% in structural fabrication labor hours downstream. Additionally, all six components in the plate processing system were produced by the same vendor; therefore, parts such as motors and controls are common, which has eased maintenance requirements.

Energy Management System

Electric Boat Corporation, Quonset Point Facility realized many benefits from implementing a PC-based Energy Management System to control heating, ventilation, air conditioning units, air compressors, steam valves, boilers, and lights throughout the facility.

Electric Boat Corporation, Quonset Point Facility's (EBQP's) heating, ventilation, and air conditioning (HVAC) units, air compressors, steam valves, boilers, and lights were independently controlled. This required a maintenance technician to go to a specific unit to take readings of critical operating parameters to determine if the device was functioning correctly. Operating equipment independently was inefficient in terms of cost and energy.

EBQP implemented a PC-based Energy Management System (EMS) to control HVAC units and steam valves, monitor electricity and argon consumption, and regulate air compressors. Using Carrier Comfort Works' software and sensors, the EMS performs two major functions by constantly monitoring critical facility operations via sensors, and controlling standard on/off processes so output is proportional to demand. This PC-based system also monitors alarm points, and sends visual warnings to designated computer terminals and pagers when triggered. Monitored alarm points include air compressor inter-cooler temperatures, oil temperatures, air pressure, HVAC air handling fans, office space temperatures, relative humidity, carbon monoxide content, and temperature parameters in critical areas.

Currently the EMS controls the office space temperature to within a one-degree variance by using an algorithm to read the outside air temperature, current space temperature, and desired temperature. Based on these inputs, the system adjusts the heating valves, cooling valves, and outside air dampers to maintain the set point temperature. The EMS constantly monitors the compressed air system to maintain the desired air pressure. As pressure drops due to higher demands, the program ramps up the lead compressor to a higher output. If this is insufficient to meet demand, the EMS brings the secondary compressors on-line. Once the desired pressure is achieved, the system will begin to ramp down the compressors to avoid over-pressurization. Based on the outside air temperature, the EMS automatically adjusts the steam heat valves and the chiller plant to heat and cool the offices.

The EMS allows EBQP to operate more efficiently, and has saved thousands of dollars in annual energy costs. Maintenance personnel can now monitor all critical operations through a computer without needing to examine a specific operating unit.

Facility-Wide Communications Program

Electric Boat Corporation, Quonset Point Facility believes that a well-informed workforce leads to a more rewarding and safer workplace that nurtures creativity, rewards achievement, and is results-oriented.

Electric Boat Corporation, Quonset Point Facility (EBQP) recognizes the importance of having an effective communications program that serves as a tool for clearly disseminating announcements, updates, policies, and procedures throughout the facility. During its downsizing, the necessity to maintain the lines of communication for security and safety issues was crucial. However, the exchange of general information diminished due to resource constraints. With the rebuilding in recent years, EBQP re-established or created a number of effective communication mechanisms to meet the needs of a leaner, more diverse, and novice workforce.

Living up to its mission statement, "Through a strategic communications plan, we strive to keep our employees informed with valuable information that contributes to their quality of worklife," EBQP implemented several communication tools to keep the flow of information between the company and the employees a two-way street. An open-door policy is in place with every manager throughout the facility to enable employees to share their ideas and concerns to improve the company as a whole. Employee events have been an excellent method of communicating with the workforce to increase morale. Morning musters keep all employees informed of time-critical information, while written publications offer an excellent method of recognizing employees for pro-active suggestions and changes to production efforts.

Several publications are written weekly, monthly, and quarterly to acknowledge the efforts of employees and employee teams, share business information, and keep everyone informed of the successes and potential struggles of the business. Some of these publications are mailed directly to employees' homes while others are made available at several locations throughout the facility. The weekly

publication offers articles on issues such as safety, quality, road construction detours, community events, recreation opportunities, reports, and company lean event accomplishments. Each newsletter contains safety issues with a sign-in sheet that the production floor supervisors use while conducting weekly stand-down meetings with all employees to ensure pertinent information has been communicated throughout the workforce. EBQP also recognized the importance of face-to-face communications. Four staff members from the Human Resources department spend at least 13 hours per week walking the production floor, talking with employees, and discussing issues and ideas to improve the company.

The Facility-Wide Communications program enables EBQP to keep its workforce informed on the latest information regarding security, safety, and general issues. By utilizing readily available technology and innovative methods, the company finds new ways to effectively communicate important points to its targeted audience — an industrial workforce engaged in heavy fabrication and outfitting to very exacting specifications with critical safety and security requirements.

Infrared Thermography Based Predictive Maintenance

Electric Boat Corporation, Quonset Point Facility uses an infrared camera to simplify the process of interpreting and finding problem areas in electrical panels.

Electric Boat Corporation, Quonset Point Facility (EBQP) has more than 1,000 electrical distribution panels, each having the potential to cause loss of production or a catastrophic fire in the event of a failure. The standard practice for checking/maintaining electrical panels was to have an electrician drop power to the panel and manually check every connection. This was labor and time intensive, costly, and typically took four hours per panel.

EBQP purchased an infrared thermal imaging (thermography) camera to inspect electrical panels. This camera allows the panel cover to be opened, and while the panel is still energized, the camera can check every connection within 30 seconds. Hot spots noted in the thermal image can be saved and downloaded to an electronic report for scheduled

repair. This process can also be performed on overhead, high-power lines which, on one occasion, immediately identified a severe problem with a piece of utility-owned, high-voltage equipment that was adversely affecting EBQP's power supply.

The thermal imaging camera proved its value when the utility power supply to the Blast and Paint Facility had caused numerous single-phase events in the building. Each event caused a total loss of power and interruption of production, at a cost of up to two hours per event. In less than two minutes after restoring power to the building, the infrared camera pin-pointed a faulty connector on the utility pole. By simplifying the process of finding a problem area in electrical panels, an electrician now spends one or two hours every night surveying several panels with the camera, as opposed to spending four to six hours for a single panel.

Proactive Environmental Resource Management

Electric Boat Corporation, Quonset Point Facility is a leader in adopting environmentally-friendly practices. The company's Environmental Policy fosters the implementation of environmentally sustainable processes, pollution prevention, and continuous improvement in the design, construction, delivery, and repair of submarines.

Electric Boat Corporation, Quonset Point Facility (EBQP) is an industry leader in proactively responding to environmental responsibilities. Addressing environmental concerns during the development of processes and products improves efficiency and identifies opportunities for cost savings. A proactive approach banks regulatory relief, whereas a reactive approach yields costly compliance. EBQP actively incorporates new U.S. environmental standards prior to issue or as they were being promulgated. In 1973, EBQP leased the abandoned Naval Air Rework Facility, without understanding the environmental neglect of the ground contamination which had taken place during the previous occupant's tenure. After a thorough assessment, EBQP was faced with insurmountable challenges regarding legal liability, treatment alternatives, and project funding. EBQP, in concert with the Army Corps of Engineers, proactively catalogued the extent of con-

tamination and elected to pursue physical remediation instead of adopting a containment approach. This experience reinforced EBQP's timely transition from reactive to proactive environmental resource management as U.S. environmental policy-making accelerated in the 1990s.

Elimination of sub-surface contamination is one of many environmentally-friendly initiatives EBQP has facilitated. Other proactive measures include replacement of electrical transformers in more than 50 buildings in support of 100% extraction, removal, and disposal of polychlorinated biphenyls. EBQP also removed all underground storage tanks and replaced them with above-ground, environmentally-compliant units. Significant gains have also been made in the reduction of airborne emissions of volatile organic compounds (VOCs). With the new Virginia Class submarine construction, EBQP reduced solvent-based cleaners from 77 to 15, adhesives/fillers from 148 to 67, paints from 107 to 67, and completely eliminated Class I ozone depleting substances. With the installation of HEPA particulate accumulators on major processing equipment, the exterior vents have been eliminated, yet clean, breathable air is still returned. Pipe cleaning operations were modified to reduce waste disposal, and many painting operations have been moved to the environmentally-friendly powder paint process, significantly reducing VOCs. In recognition of this accomplishment, EBQP was presented with the 2001 Governor's Award for Outstanding Achievement in Pollution Prevention for the newly constructed, large part, powder coating facility.

Key to EBQP's success has been full employee participation in identifying and documenting all major process flows. With input from process owners, environmental impacts associated with each process were listed. This allowed EBQP to identify environmental risks, avoid unnecessary liabilities, and promote pollution prevention. Recently, EBQP developed an Environmental Permit Management System to satisfy regulatory requirements for its Title V Air Permit. Metrics for more than 900 items that could potentially impact the environment are being certified to ensure compliance. EBQP underwent an ISO 14001 Environmental Management System (EMS) certification audit in 2003, and has been certified ISO 14001 compliant. The EMS will further enhance environmental awareness and the structure needed to achieve environmental improvement.

Target Vision

To keep employees informed of important information in real time, Electric Boat Corporation, Quonset Point Facility installed Target Vision TV and Readerboards throughout the facility.

Electric Boat Corporation, Quonset Point Facility (EBQP) occupies 85 acres with 14 acres under roof. Attempting to communicate important messages to employees over such a large span of space was difficult. Needing a method that was wide-range and consistent to disseminate important information throughout the organization, EBQP deployed Target Vision, commonly known as EBTv. Target Vision incorporates 13 televisions and three Readerboards into a message system that is accessible to all employees in all areas.

The televisions and Readerboards are located in high-traffic areas where employees can take a few seconds to obtain information on a wide variety of topics, including General Dynamics' announcements, emergency information, Electric Boat events and announcements, weather, news, sports, and stock quotes. Target Vision "slides" display information in an easy-to-read format with differing backgrounds for each message. The Readerboards are a scrolling source of information similar to the method used to display stock prices. Just as with the televisions, Readerboards provide an instant information source for employees at work.

With an abundant amount of information to disclose, EBQP needed an easy-to-use software system. The company adopted a system called Enterprise Edit, which enables an administrator to create and edit the information on the Readerboard and the television. This has proven to be very suitable in communicating information in a timely manner.

The EBTv System can be utilized to broadcast video training to teams of employees. A selected training video will run at specific times during a two-week period to enable a production supervisor to select a time that best fits a production schedule without the burden of scheduling a trainer to fit production schedules or making shift changes.

The implementation expense for Target Vision was less than \$150,000 and has been beneficial to labor and management as a real-time, flexible solution to the communication needs of the facility and the corporation.

Management

Accuracy Control and Three-Dimensional Measuring and Modeling

Electric Boat Corporation, Quonset Point Facility's Accuracy Control and Three-Dimensional Measuring and Modeling processes are accomplished using four major steps: definition of measurement requirements; implementation and accomplishment of those requirements; evaluation of collected measurements; and adjusting the process to compensate for variation in interim-product assemblies.

Electric Boat Corporation, Quonset Point Facility (EBQP) defines Accuracy Control as "the measuring of selected dimensions during manufacture, assembly, and outfitting to allow in-process adjustments to ensure the final product meets the drawing requirements, readily fits to mating the parts and achieves system functional needs." EBQP's former processes during manufacture, assembly, and outfitting did not control accuracy, but rather accounted for inaccuracy within a nominal margin to allow for custom fit-up or "pairing" of large, dimensionally-complex assemblies. Much of the latter assembly work required on-board machining, which had a significant impact on the scheduled work for other trade areas. No data was gathered on the "as-built" condition of an area where a tight tolerance had to be met for another mating outfit assembly. The method of assembly was more system-oriented than modular, zone, or interim product-oriented. Using the previous method, typical cycle time for one submarine was approximately five years.

The current state-of-the-art process employs Accuracy Control and Three-Dimensional Measuring and Modeling to support modular, zone, and product-oriented design and construction. EBQP uses four major steps and a broad range of sophisticated hardware and software to accomplish these goals. Using the four steps of definition, implementation, evaluation, and adjusting with multiple tools allows flexibility in various applications so the most appropriate means can be used to achieve the best results. The four steps are further described as: definition of measurement requirements; implementation and accomplishment of those requirements; evaluation of collected measurements; and adjusting the process according to variation, the key

for accurate assembly. Integrating the measurement results from multiple groups of dimensionally-complex assemblies is a significant challenge that requires a high degree of experience to produce quality major components that fit together without unintended interference. Considering the size, dimensional complexity, and weight of the assemblies that EBQP pairs without error is a world-class accomplishment. Delivery of a major submarine module having perfect tolerance at 99% completion and a reduction in cycle time to four years for the manufacture of one submarine are evidence of the world-class nature of this practice.

Automated Online Personal Protective Equipment and Restriction Certification

In 1998, Electric Boat Corporation, Quonset Point Facility upgraded its Automated Time and Attendance system to provide easy notification and accessibility regarding physical work restrictions. This system also handles personal protective equipment requirements and training per Occupational Safety and Health Administration regulations.

In the past, Electric Boat Corporation, Quonset Point Facility (EBQP) used restriction reports to notify supervisors of their employees' physical work restrictions. The Human Resources department entered the information into a logbook and forwarded a copy to the employee's supervisor. After receiving the copy, the supervisor placed the report in the employee's file. This information normally fades from memory. Since many EBQP personnel are multi-trade qualified, they are routinely moved from one department or area to another. Many times the restriction information does not get passed to the new supervisor. As a result, employees often were assigned tasks beyond their physical restrictions and incurred subsequent injuries. This system of restriction reporting meant that medical personnel and supervisors had to manually search employee and medical files to locate an employee's work restrictions. In 1998, EBQP addressed these issues by upgrading its Automated Time and Attendance (AT&A) system to provide easy notification and accessibility regarding physical work restrictions. At that time, the company also adjusted the AT&A system to handle personal protective equipment (PPE) requirements covered by work

restrictions and training per Occupational Safety and Health Administration (OSHA) regulations.

The upgraded AT&A system is user-friendly and easy to maintain. Only the Human Resources department is authorized to enter employees' physical work restrictions and PPE requirements and training into the system. Human Resources personnel also enter any follow-up or restriction review dates into the system. If an employee fails to keep an appointment with Human Resources for restriction review or follow-up, he or she is locked out of the AT&A system, thereby alerting supervision. This task is completed on a daily basis, and the information is updated as needed. Supervisors can quickly access the information to verify daily labor hours, determine equipment and training needs, and assign tasks within each employee's capability. Since no specific medical information is provided, the work restriction feature does not violate employees' rights.

The features of the AT&A system provide EBQP with many benefits. Supervisors now access up-to-date information on their employees' physical work restrictions, PPE requirements, and training, and can initiate appropriate actions (e.g., determine task assignments, issue proper equipment, provide additional training). Medical personnel easily obtain this information without manually searching an employee's medical file. In addition, the AT&A system is designed to generate reports that track the number of employees in each work restriction category. Since implementing the upgrade, EBQP notes an absence of occupational injuries for situations where employees were performing tasks beyond their physical restrictions.

Complaint Report and Employee Q&A

Electric Boat Corporation, Quonset Point Facility developed and implemented a tool which provides information on issues that concern employees and require management's attention to resolve as they arise. This management tool is also used to identify potential problems and solve them before they become employee problems.

Electric Boat Corporation, Quonset Point Facility (EBQP) was the subject of a union-organizing campaign. It was during this campaign that a number of important employee issues were first realized. In response, the company compiled these is-

ssues into a database, and each issue was assigned to a responsible party/member of management for resolution. As of the election date, approximately 85% of the issues were resolved and the company subsequently prevailed. However, realizing the importance of not only listening to employees but also quickly responding to them, EBQP developed and maintains an employee complaint database to document complaints. By updating and maintaining the database and communicating with employees, and regularly acting upon complaints, it is a dynamic employee relations tool.

To proactively obtain employee issue information for investigation and resolution, a number of programs, procedures, and practices were developed and implemented. An employee complaint database was developed to track employee complaints on a number of data points to identify, track, and proactively resolve "hot" issues or potential problem areas. These data points include ethnicity, type of complaint (e.g., harassment, application of policies), shift, superintendent, and gender. Because the combined practices of listening and responding were important, the data point of turn-around time was tracked to determine timeliness of resolution, and if problematic, evaluate opportunities for greater efficiency. Data is primarily obtained from meetings with employees who have a complaint (defined as requiring more than one day of research to resolve). As an additional tool for analysis and communication, an Employee Q&A database was developed. This database is largely an outgrowth of the one developed during the recent organizing campaign. As of mid-2003, many issues are in the database with approximately 95% of them resolved.

Information is obtained through a formal walk-through schedule that was purposely developed and implemented for the Employee Relations staff. Prior "floor time" was erratic and generally at the mercy of project work. To overcome these difficulties, a schedule was developed that ensured equal floor time across all locations and shifts. This schedule provides 13 hours of floor time per week. While on the floor, Employee Relations representatives obtain and document employee issues for resolution. If any of these issues rise to the complaint level, they are included on the complaint report; otherwise, the issue is incorporated into the Employee Q&A database. The database is updated and maintained on a quarterly basis. Employee issues have been resolved in the following ways:

- Development of new policies to ensure con-

sistency in application

- Evaluation and purchase of new equipment
- Implementation of new benefit programs (e.g., salary/hourly pension benefit)
- Communication (e.g., development of seniority database and placement on central computer drive for immediate access)

Although EBQP has an open-door policy, the management found it difficult to keep track of each complaint. Complaints were sometimes not dealt with properly and were not responded to in reasonable time. The Complaint Report allows everyone concerned to be kept up-to-date as to when the complaint was made and by whom, the individuals involved, the nature of the complaint, whether or not an investigation was done and by whom, any action/resolution that resulted, and the length of time it took to resolve the complaint.

This documentation is a report card for the Employee Relations Department. The information included in the report also helps track possible trends with complaints. For example, the periodic analysis of these reports reveals major sources and locations of problems, types of concerns, and whether or not follow-up investigations were done in a timely manner. The report is a valuable management tool to ensure that complaints are dealt with professionally and consistently. The information generated is presented directly to the responsible superintendent for tracking problem issues and focusing on where improvements need to be made.

Communication is a key component of these analytical programs. Communication of the complaint report results is achieved through the development of comprehensive management reports. An executive summary was developed for upper management to communicate and address global areas of concern. Individual meetings are held with superintendents to review the report and communicate meaning and potential resolution strategies at the mid-organization level. Employee Q&A results are sent through multiple channels to ensure maximum customer delivery. Employee communication on major policy changes or new programs is achieved through team meetings which are hosted and presented by management.

Continuous Improvement Program

Electric Boat Corporation, Quonset Point Facility's management views continuous improvement as one

of its critical success factors. Top management actively endorses and supports a wide variety of team-based activities focused on utilizing the "wealth and experience" of its employees to eliminate waste from all business processes.

Process improvements are small changes that put employees' ideas into action and result in enrichment for the company. In the past, Electric Boat Corporation, Quonset Point Facility (EBQP) attempted to improve its business base through a variety of techniques including Quality Circles, Suggestion and Recognition programs, and Best Practice teams. Despite their general success, these techniques were often segmented and compartmentalized. Seeking a more effective way to capitalize on process improvements, EBQP developed the Process Improvement Program (PIP) in November 1997.

PIP is a comprehensive and integrated program, which focuses on the capabilities, experience, and ideas of the workforce for implementing process improvements. Key to this program is Process Improvement Teams, which are formed within and across eight functional areas. This approach promotes participation by employees, enhances communication, and limits discord by understanding the value of individual contributions. The teams are comprised of five to six hourly and salary employees, depending on the functional area. The teams are responsible for identifying problems, proposing solutions, and determining drivers for improvement. PIP provides additional services through a staff administrator and up to 20 facilitators who assist the teams, benchmark PIP methods and techniques, and provide specialized assistance and training as needed for problem-solving and goal-setting processes. PIP employs a Process Improvement Template, an easy-to-use tool format that processes improvements into standardized categories (e.g., area(s), section(s), concern, action, status, acceptance date, and implementation date). This Microsoft Access-based system provides real-time access enabling management to view, track, and analyze process improvements. The system also features search capabilities and a report generator allowing the creation of reports based on established parameters (e.g., functional area, types of change, department, shift, and/or incentive for improvement). Using the Microsoft PowerPoint link, the templates and reports can be viewed or downloaded for team meetings and management briefings.

The program continues to grow and expand. Currently, it is known as the Continuous Improvement Program (CIP). In recent years, Lean Manufacturing principles were incorporated into the program. Training was provided through Worcester Polytechnic Institute, and the tracking system was modified to include various forms of Lean projects. The Access database is being converted to an Oracle database and will reside on the company's Intranet so Continuous Improvement (CI) information will be available to all General Dynamics operating divisions. Because of the growth in these types of projects, a full-time process analyst has been added to the staff. EBQP is now training selected team members in Six Sigma methods to further enhance and expand the program.

The most important element to the CIP's success is employee participation, which the company defines as an employee being a member of one or more teams within a one-year period. The individual who suggests the CI project is either responsible for its implementation or is a key participant on the CI team that takes it to conclusion. In 1998, employee participation in PIP was almost 45%. Last year, the company achieved a participation rate of 80%, accepting 668 new improvement ideas and successfully completing 653. EBQP's database now contains more than 3,500 improvement ideas generated by team members, and the program continues to expand with 85% employee participation and 75% implementation rate goals for the current year.

Cost of Quality Program

By using accurate data collection and trend analyses, Electric Boat Corporation, Quonset Point Facility effectively measures the cost of quality and assesses the effectiveness of corrective actions used in the reduction or elimination of defects.

Safety and quality are essential ingredients to build the most capable and safest nuclear submarines that an industry can produce. Accordingly, the cost of rework and repair (or cost of quality) has always been an industry topic

of conversation. Shipyards commonly measured only one attribute at a time and calculated the number of rejections versus the total number of submittals. This effectively calculated the rejection rate, but omitted the hourly level for reworking and repairing defects. In 1998, Electric Boat Corporation, Quonset Point Facility (EBQP) initiated a Cost of Quality program to measure the overall performance versus quality.

Principal indicators of facility quality were identified and documented, as well as the best available rework estimate associated with each event type. Available data for these elements (e.g., welding rejections, customer concerns, out-of-tolerance reports, errors, or rejections) are gathered and compiled monthly. The standard rework estimates are then used to determine the cost of rework and repair. The cost of quality index is then established by dividing the cost of rework and repair by the total manufacturing labor cost expended that month at the facility. Standard rework estimates are also regularly assessed to ensure they are currently representative.

The available and calculated quality measures are reviewed monthly at the Corrective Action Board together with possible solutions to reduce or eliminate rejections. The associated metrics are also trended and graphed to show variations and the effects of corrective actions. This effort has been successful in maintaining EBQP's cost of quality indexes below 1.5% for the past five years as shown in Figure 2-10.

The data enables EBQP to identify and quantify its quality problems. That, in turn, enables the company to effectively focus on and control the most expensive elements driving rejections. It should also

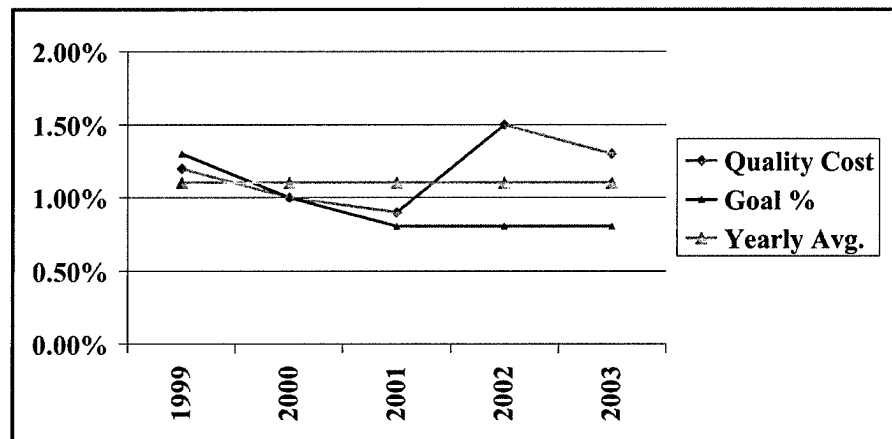


Figure 2-10. Quonset Point 5-Year Summary

be noted that this successful level has been maintained during a period of significant reductions in the quantity of submarine construction.

Discipline Process

Fair, consistent, and equitable treatment of employees is a major management objective at Electric Boat Corporation, Quonset Point Facility. This is particularly true in the disciplinary process where supervisors subjectively can compromise consistency and equity. To prevent this from occurring, management delivered and implemented a uniform standardized process to ensure supervisors use the same process in taking disciplinary action.

Ensuring that discipline is consistent and fair to all employees throughout the facility is a major focus at Electric Boat Corporation, Quonset Point Facility (EBQP). However, with more than 100 supervisors and nearly 2,000 employees, it presents a difficult task. EBQP believes the three cornerstones of an effective discipline program are equity, communication, and administration.

EBQP's disciplinary process historical database (spanning the previous ten years) documents all disciplinary actions, and all new and potential disciplinary actions are "bumped up" against this database to ensure consistency and equity in application. To complement this proactive approach, EBQP implemented a Dispute Resolution Policy (DRP) requiring the resolution of workplace disputes involving legal claims through the DRP. The DRP is working as expected, and disputes are being resolved fairly, quickly, inexpensively, and to the satisfaction of employees. Provisions of DRP are intended to resolve claims involving trademarks, business secrets, business technical know-how, and intellectual property. DRP does not prevent an employee from filing a claim with the EEOC or any other governmental agencies. Also under the provisions of DRP, an employee or the company can apply to court for interim injunctive relief for claims involving intellectual property, trade secrets, business technical know-how, non-competition, non-solicitation, and fiduciary or confidentiality obligations. DRP allows spouses or significant others to attend mediation or arbitration proceedings.

EBQP was reminded that the second cornerstone of an effective discipline program is reliable commu-

nication — specifically, the effective and consistent delivery of discipline. It was during the course of the first few DRP challenges that EBQP realized its program was faulty in this respect (e.g., forms were inconsistent, verbiage was inaccurate, and the program could be compromised). As a result, the company developed and instituted a two-pronged approach. First was the development, communication, and implementation of a discipline policy which, for the first time, outlined critical methods for administering and delivering discipline. Next was the development and implementation of standardized discipline forms which were placed on a shared electronic drive. The latter effort ensured that all discipline forms were consistent in presentation and format, and that discipline was delivered and communicated in a timely manner. In the past, supervisors could not independently access these forms; instead they had to wait for assistance from administrative assistants who were only assigned to the first shift. With the placement of these forms on a shared drive, all supervisors, regardless of the shift or administrative support, can immediately access a discipline form, update it, print it out, and deliver the action the same night, after first consulting with a representative from Human Resources.

The third cornerstone, experience, proved that the effective administration of discipline can only be achieved through effective training. In the past three years, a significant number of new supervisors were hired. Although they received generalized training, it was apparent that more specific training was needed in the discipline program and its proper administration. To meet this need and further strengthen the program, a Discipline Training Program was developed and delivered to all supervisors. During the training, the new discipline forms were introduced and a training evaluation form was developed to assess the program's effectiveness. Feedback regarding the program itself was overwhelmingly positive. The result is that discipline is now being administered more consistently and in a timely manner, thus strengthening the connection between behavioral and procedural deficiencies and the need for improvement. During the development of the standardized disciplinary forms, a recognition form was also developed for supervisors to use as a means to recognize employees in a timely and meaningful manner.

Fire and Tank Safety Technician Program

Electric Boat Corporation, Quonset Point Facility consolidated a wide range of life safety-related functions into one group. The Fire and Tank Safety Technicians brought discipline, cross-training, and importance to an integrated approach in achieving safety for all. The professionalism energized the workforce in a positive manner, significantly leveraging their own efforts, and drastically reducing fires and alarms at the company despite an increase in workload and new employees.

At Electric Boat Corporation, Quonset Point Facility (EBQP), safety is always the first priority with the construction of our nation's nuclear submarines. Fire and tank safety traditionally pose some of the most serious challenges and routinely were managed separately. Because of their importance and recognizable interrelationship, EBQP combined their responsibilities and placed them into one group under the Fire Marshal's Office.

Currently life safety is a coherent function with significant cross-training for Fire and Tank Safety Technicians. This was also accomplished concurrently with modular construction advances that created increasingly more complex confined spaces, associated challenges for confined space rescues, and significantly upgraded Occupational Safety and Health Administration (OSHA) guidelines for confined space entry. The consolidation made these technicians responsible for a diverse range of life safety-related skills including all the fixed and portable extinguishing systems, code compliance (e.g., OSHA, Fire, Navy), respirators, emergency medical services, confined space rescues, and fire prevention and protection. One of the most crucial roles is the training and monitoring of life safety practices within the shipyard. These technicians are trained to Federal DOT standards as registered HAZMAT technicians and provide emergency response for all hazardous material spills. This includes everything from small spills to releases requiring suiting with a self-contained breathing ap-

paratus. This group of technicians is comprised of fully cross-trained and motivated individuals who represent significant shipyard assets. Their competency is key to ensure the necessary level of life safety for all EBQP employees, visitors, and vendors. Their knowledge and efforts have established significant employee involvement and competence. By virtue of this consolidation, one group has recognized responsibility and control over confined spaces from certification to potential tank rescue.

Employing a proactive preparedness approach, the technicians never stop training (themselves or others) to prepare for possible challenges. Consequently, their skill and effort is both admired and emulated by EBQP employees regarding life safety. Although EBQP has increased its workload and number of new employees over the last twelve months, the excellent results of these technicians is evidenced in the drastic decline in both fires and alarms at EBQP over the past year (Figure 2-11).

Electronic Record System

Electric Boat Corporation, Quonset Point Facility's Electronic Record System improved weld data accuracy, greatly simplified the overall process, and incorporated expanded features while significantly reducing the cost of data collection and storage.

Electric Boat Corporation, Quonset Point Facility (EBQP) developed a Shipyard Weld Status System (SWSS) to capture the completion of weld joint work and provide assurance that weld accountability meets the Navy's SUBSAFE requirements. The SWSS capabilities were enhanced for the Virginia

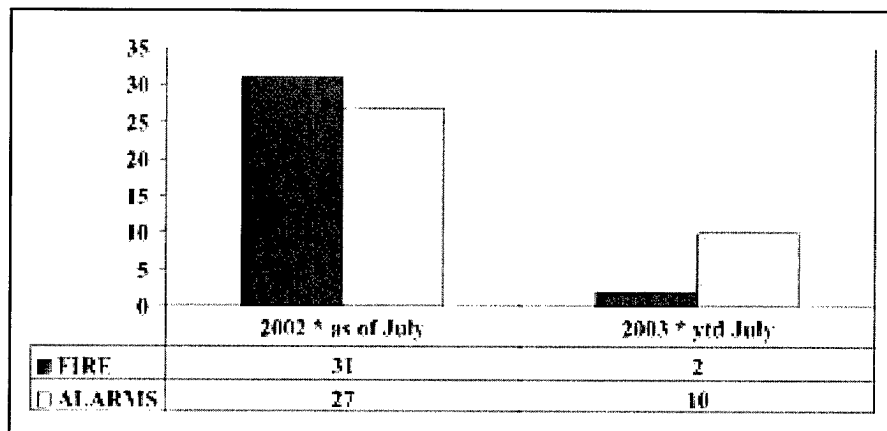


Figure 2-11. One-Year Reduction Chart

Class submarines by establishing the Electronic Record System (ERS). Previously, SWSS relied on hard copies for maintaining records. A printed card was generated with weld joint information, provided to the worker to record activity completions, subsequently manually entered in a database, the card retained, and eventually placed in long-term storage. Approximately 300,000 cards were required for each submarine.

For the Virginia Class, the ERS replaced these transactions with a series of computer interactions. Design data for the weld is directly accessed from the SWSS database and routed through a logic phase that delineates the complete routing path for each weld. This information is available at local workstations where the trade foreman can preview the workload and assign an employee to each activity. Employees update the ERS upon activity completion. This can be done simply by scanning their security badges through a magnetic strip reader to access the system, enter the new information for the activity, and re-scan their badges for confirmation. A number of related information fields can be efficiently verified at the same time. These include validation of an individual's qualifications to sign-off the particular activity, monitoring ship completion progress, and attendance data.

Data accuracy was an obvious improvement, as was the cost of data recording and storage. Added benefits were also realized. The system not only prevents activities from being done out of sequence, it also ensures that appropriate time delays are observed prior to inspector conduct, or sign-off for Non-Destructive Testing (NDT) after hot work is performed. Consequently, it is already being used division-wide within General Dynamics, and has also been implemented by Newport News Shipbuilding (NNS) and Dry Dock for their submarine work.

Employee Community Services Association

Electric Boat Corporation, Quonset Point Facility's Employee Community Services Association is an effective community outreach program that benefits local, non-profit, charitable organizations and employees in times of need.

Electric Boat Corporation, Quonset Point Facility (EBQP) established the Employee Community Services Association (ECSA) as an outreach program to help employees and the community. Set

up as a non-profit organization, ECSA is certified by the Rhode Island Secretary of State's Office and is managed by the ECSA committee comprised of hourly and salary employees who represent a cross-section of the workforce. The committee oversees the collection of funds through payroll deduction as well as the distribution of donated funds to various charitable organizations and to the catastrophic needs of fellow team members.

The ECSA Committee meets monthly to review monetary requests from organizations. To qualify for donations, the requesting organization must be non-profit and benefit the welfare of Rhode Islanders, nearby communities, or any EBQP employee and/or their family. If the criteria are met, the committee votes on whether to donate to the specific organization. The amount donated is based on the services provided and the organization's size and number of people served. To show employees how their donations are distributed, thank you notes from organizations are posted on bulletin boards, and donations are listed in the Weekly Information Bulletin.

The committee also holds emergency meetings whenever an EBQP employee suffers a catastrophic event that causes an immediate financial hardship. Again, certain criteria must be met prior to receiving monetary assistance. The Committee then votes on eligibility and the amount to be given. In these cases, donations to individual employees are kept confidential. Recent distribution of funds has been to the United Way (45%), Catastrophic Fund (20%), and a Requested Assistance to Organizations (30%), with a small percentage remaining for emergency use.

The annual campaign is held in November to coincide with the local United Way Campaign. During the campaign, a bulletin of the previous year's ECSA activity is distributed. EBQP provides prizes to employees to encourage them to become members of ECSA or to increase their donation. The annual campaign is publicized through flyers, the Weekly Information Bulletin, EBTv, Automated Time and Attendance (AT&A), and with banners placed at the gates. Committee members also staff an information table during lunch times to answer employee questions and distribute literature. EBQP has shown strong support for the ECSA by allowing the administrative work of the Committee (e.g., meetings, letter writing, payroll deductions) to be completed on company time, and by donating the campaign prizes.

In addition to monetary donations to organizations and individuals, the ECSA also sponsors and participates in other activities throughout the year including:

- Rhode Island Community Food Bank collections
- Rhode Island Special Olympics
- American Cancer Association's "Making Strides Against Breast Cancer Walk"
- Santa's Helper Program which provides gifts for 200 local needy children
- Sponsorship of employees who walk for various affiliations
- Special collections (i.e., most recently for victims of the Station Night Club Fire)

The benefits realized by the ECSA have been tremendous. The program enables employees to participate in charitable giving within the community without being solicited individually. The catastrophic fund is unique and provides a means for individuals to help their colleagues in times of need. Recognition from the community has come in the form of many awards. In 2003, EBQP was honored by the Rhode Island Association for Cardiac Children as their Corporate Sponsor of the Year. In addition, the Rhode Island Special Olympics presented the ECSA with an award for ten years of continued support, and the United Way of Rhode Island presented EBQP with the Bronze Award for five consecutive years. ECSA is an effective outreach program, strongly supported by both employees and management. During the 2002 campaign, \$130,000 was donated by EBQP employees, signifying a membership rise from 68% to 74%.

Leadership Development and Supervisory Skills Training

Electric Boat Corporation, Quonset Point Facility has a long-standing commitment to personal development of its workforce, supervisors, and management. Leadership development and supervisory skills training have been refined by adding a preparatory course for upcoming managers, foreman orientation, and the Pinnacle program. Currently, a career mapping program for foremen is being developed. Through these training programs, the company expanded the skills, knowledge, and capabilities of its managers.

Electric Boat Corporation, Quonset Point Facility (EBQP) has a long-standing commitment to personal development for its workforce, supervisors, and management. Leadership development and supervisory skills training have been refined, preparatory courses have been added for upcoming managers, and a career mapping program for foremen is being created. Through these training programs, EBQP expands the skills, knowledge, and capabilities of its managerial employees.

After downsizing in the early 1990s, EBQP began rebuilding its workforce and recognized the need to revise its management development practices. In 1998, EBQP implemented a comprehensive Leadership Development and Supervisory Skills Training Program for all management. Currently, EBQP has a more refined Training Program, and also added preparatory courses for upcoming managers, foreman orientation, and the Pinnacle Program. EBQP is also creating a foreman career mapping program. Program features include:

- **Leadership Development Training:** This program is a 24-hour, off-site course developed by the Rensselaer Learning Institute. The course provides a foundation for one-on-one interpersonal skills and focuses on techniques that support team initiatives, quality enhancements, and process improvement efforts. Participants also learn how to address leadership challenges typically found in today's cross-functional workplace where employee involvement and interaction are increasing.
- **Supervisory Skills Training:** This program is an eight-hour, on-site course developed by EBQP's Human Resources Department and is delivered in four, two-hour segments and deals with personnel issues, employee evaluations, disciplining procedures, the wage system, training requirements, safety and health topics, legal issues, and procedures for new hires. Participants also learn how to sharpen their human resource skills.
- **Preparatory Courses:** These courses are designed to prepare employees to compete for management positions. The courses are delivered in two Phases: Phase 1 is a five-day, two hours per day, on-site course that deals with setting expectations and communication skills. Participants learn functions of a supervisor, how to interview, and people

skills; Phase 2 consists of 10 to 15 hours of on-site training dealing with computer skills and organization structure. Participants learn how to process work packages, time and attendance, and organizational processes.

- **Foreman Orientation:** As positions are completed and filled, this program is being developed for selected foremen to receive orientation on transition from hourly to salary status and Coaching Core Competencies Program.
- **Pinnacle Program:** This program assesses a manager's overall managerial abilities, provides goal orientation, team building, and one-on-one coaching.
- **Foreman Career Mapping Program:** This program is being created to develop skills of current and new foremen. Participants will perform job shadowing, acting, and rotational assignments to get first-hand experience of the position.

EBQP's Leadership Development and Supervisory Skills Training Programs are a continuous process. Through these programs, the company expands the skills, knowledge, and capabilities of its managerial employees. Those who complete the training learn how to establish constructive relationships, initiate positive actions, lead by example, focus on a situation instead of an individual, and how to maintain both self-confidence and the esteem of others.

Lean Manufacturing Practices

Electric Boat Corporation, Quonset Point Facility's Lean Process Improvements for its Machine Shop's storage and distribution of tooling reduced lost travel time and safety hazards while improving tool availability, accountability, and employee moral.

Electric Boat Corporation, Quonset Point Facility (EBQP) introduced Lean manufacturing practices in all of its processes and work areas. Significant resources have been successfully devoted to providing Lean training, technical support, and staff assistance necessary for the implementation of Lean projects. A significant amount of production time was being lost due to a shortage of holders and a lack of organization in the Machine Shop's tool setting area. The area was cluttered with racks, tool-

ing was unorganized, and material was in the aisles. The congestion created safety hazards, was aesthetically displeasing to employees, and prevented the use of tool caddies in the area, which was approximately 200 feet from the machines being serviced. This resulted in poor communication between the machinists, programming, and tool setter.

A Process Improvement Team comprised of employees from various positions in the Machine Shop was organized to identify and resolve issues affecting the area. The Team reviewed the area and logistics of the location, and determined there were issues with the location of the area and the lack of equipment storage space. The Team invested less than \$1,500 in fencing supplies and approximately 65 labor hours to establish a secure location near the machines for the tool setter area. The new location has eliminated lost travel time to the crib. This move greatly improved communication between the tool setter, machinists, and foremen. The area was sized to accommodate all of the tooling, a phone was placed in the area to allow for communication between the tool setter and programmers, and the tool caddies can now be used to move tooling to and from the machines.

The new setup has proven to be an outstanding success. Tool shortages have been nearly eliminated, travel time to and from the tool setter has been reduced, and communication between the tool setter, machinists, and foremen has greatly improved.

Lifting and Handling Surveillance Program

Electric Boat Corporation, Quonset Point Facility recognized the need to enhance its Lifting and Handling Program. Accordingly, the company developed and implemented a surveillance program to monitor the lifting and handling operations and equipment in-between and outside the formal inspection process to ensure ongoing program continuity and integrity. The surveillance program identifies and addresses program deficiencies as early as possible to prevent a larger-scale problem.

Lifting and handling large complex assemblies at Electric Boat Corporation, Quonset Point Facility (EBQP) is an every day part of the operation in the boat building business. It involves skilled riggers operating cranes, rigging, slings, shackles, and other material handling equipment to lift, move, and ro-

tate extremely large, heavy assemblies throughout the manufacturing operations. If not performed with great skill and understanding to details, the safety of the products, equipment, and personnel can suffer. To ensure safety and procedural compliance, EBQP implemented a Lifting and Handling Surveillance Program in 2001.

Previous to the Surveillance Program, trade personnel and riggers received a four-hour classroom instruction that provided general understanding of the use and inspection of lifting and handling equipment. Workers then returned to the shop floor where they resumed various lifting and handling operations, still using equipment that was not always functioning properly or was damaged. Supervisors oversaw the work, but often were unfamiliar with sound rigging practices. Cranes were in constant need of repair, and rigging equipment was often damaged through abuse and misuse. Employees were performing lifts beyond their training level, and performance was not being measured. As a result, accidents were on the increase and not always being reported, and performance was not being measured.

EBQP established a team to survey the entire lifting and handling program and take a closer look at the quality of work being performed by senior riggers and trade personnel. The team's investigation uncovered numerous problems with the existing program. Navy Crane Center (NCC) was invited to conduct an inspection, and they also found serious weaknesses in the program that required immediate attention. Other shipyards, as well as NASA, were also contacted to benchmark the practices being used to effectively monitor the lifting and handling programs. EBQP developed a program from this information.

EBQP now has an 18-member team, with representatives on each of the three shifts, performing lifting and handling surveillance. Each team member is responsible for ensuring program compliance in accordance with documented instructions and identifying potential problems based on a checklist of 74 deficiencies common to the industry. To prepare for the assignment, team members receive in-house training on the documented program requirements, deficiency attributes, and training from the rigging hardware manufacturers (e.g., The Crosby Group, ACCO Chain, and Lift-All Sling). Any deficiency noticed by a team member during surveillance is documented. To positively reinforce good work practices, tasks being performed to standard

are also documented. Deficiencies are brought to the attention of the individual performing a lift so the problem can be corrected. When a lift is being performed within the standard, the person performing the surveillance acknowledges that fact. A deficiency coding system helps track trends and identify repetitive problem areas. The teams from each shift meet weekly to review reports, share observations, discuss crane and rigging accidents, and root cause. Information from individual reports is placed in a database and used to generate reports showing trends and problem areas. These reports are shared with supervision during monthly meetings and reviewed quarterly with all personnel qualified to perform lifting and handling operations.

The last audit conducted by the NCC found EBQP to be in near-perfect compliance. Good work practices are reinforced, and the condition of cranes and rigging equipment has greatly improved. Personnel are better trained (from a four-hour session to eight hours) and have greater awareness of proper lifting and handling techniques. Workers are now required to pass a two-hour evaluation where they are required to inspect hardware and perform an actual lift, and supervisors have a better understanding of the capabilities and limitations of their employees. EBQP experienced a cultural change, whereby workers who are qualified to perform lifting and handling operations now take ownership of the process.

Manufacturing and Production Engineering Program

Electric Boat Corporation, Quonset Point Facility's Manufacturing and Production Engineering Program is similar to an internal research and development program. The program's major focus is the transfer of practices to current or near-future improvements in safety, productivity, quality, and/or cost savings. Within these four areas, projects are proposed, evaluated, and awarded in the major disciplines of manufacturing and production engineering.

Electric Boat Corporation, Quonset Point Facility's (EBQP's) Manufacturing and Production Engineering Program is a continuous improvement activity of development and/or implementation of technologies that ultimately lead to safer, more productive work practices or result in higher product quality, lower cost, or faster delivery. Previously, EBQP used

a "stove-pipe" process where many of the projects for product or process improvement were a function of individual departments acting independently from other departments. This process often led to redundant efforts and conflicting objectives between departments where budgets for more widespread improvements were in competition.

EBQP's new process ensures centralized authority for determining project relevancy and potential benefit across multiple departments. The program manager has the authority to ensure that all proposed projects support the objectives of the corporation overall. The new practice also ensures a process for individual management with oversight by central authority. The operation is organized by group areas, which aids in the prioritizing of budget allocation and accountability to the sponsors. Principal investigators are internal people responsible for proposing and ensuring execution of project plans, but outside expert support may be sought where internal competencies are not available. Currently, EBQP is using this new system in projects that include areas of material control (reduced movement), work content identification (laser marking), and machine tool control (direct data input).

Multi-Trade Apprentice Program

Electric Boat Corporation, Quonset Point Facility's Multi-Trade Program is a cooperative effort by the company and employees where both benefit. The company benefits by reductions in cost and schedule, and the employees gain valuable education and knowledge of several trades. Both gain from improved employee morale as well as the workers' appreciation of the needs of other trades in the total shipbuilding process.

Electric Boat Corporation, Quonset Point Facility (EBQP) previously used a sequential process for constructing submarines in which individual trades were scheduled in a specific order. This resulted in lost time when the sequence was broken. With defense cuts reducing budgets and submarine production rates, this inefficient approach was no longer an option. EBQP responded with the Multi-Trade Apprentice Program to improve modular construction and foster a flexible workforce. Through this program, trade workers were offered extensive training in alternative

trades including ship-fitting, welding, pipe fitting, mechanical, ventilation, electrical, and sound damping. The goal of the program was to train workers in three trades outside their specialty.

EBQP organized the Multi-Trade program under a single management unit (i.e., Modular Construction). This approach allowed skills to be used where they were needed most, and it reduced direct competition among trades for the available skilled workers. In addition to improving scheduling efficiency, the Multi-Trade approach provided an ideal tool for addressing fluctuations in manpower requirements. Although this program worked, it was difficult to keep skilled workers from permanent assignments in their core skills. To strengthen the multi-trade approach, EBQP recently revised the program to a more formal Multi-Trade Apprentice Program.

Currently, 76 apprentices are enrolled in the program, which includes a required course of study at the Community College of Rhode Island (CCRI). In order to make the program as attractive as possible, an apprentice's studies through CCRI result in an Associate's Degree in Applied Technology Sciences with a concentration in Management, Engineering, or Production Control. Students also receive college credit for life experience for on-the-job work. Related training in EBQP trades consists of instruction in four trades that the apprentice selects from six possibilities: Outside Electrician, Outside Machinist, Pipefitting, Shipfitting, Welding, and Sheetmetal. With each trade rotation, the apprentice receives 96 hours of classroom training, done two days per week, four hours each class, for 12 weeks (48 hours are paid time and 48 are unpaid).

An apprentice must perform a minimum of 1,000 on-the-job hours in each trade. In addition to those core hours, the apprentice must also work supplementary hours in other areas of the facility to get a well-rounded background. The supplementary hours include 160 hours in planning, 200 hours in Non-Destructive Testing (NDT), and 200 hours in another field (e.g., engineering, management). At the completion of the on-job-training hours in each trade, the apprentice is required to pass a practical demonstration of the skill. This demonstration, which is unique to each of the disciplines, ensures that the apprentice has received sufficient training in each of the trades.

The Multi-Trade Apprentice Program is structured to make best use of an apprentice's time, and be completed in four to four-and-one-half years.

CCRI studies are scheduled to start on a regular college semester basis in September and January. Each apprentice takes two classes each semester (a total of four per year), and all trade training is scheduled for the 12 weeks of non-school time in June through August.

Since implementing the Multi-Trade Apprentice Program, EBQP improved the efficiency of its modular construction process, increased the flexibility of its workforce, and gained significant cost savings. Using a multi-trade approach during modular construction of the Seawolf Class of attack submarines, EBQP reduced applied labor hours by 25% from the first ship to the third ship in this class, and similar results are being achieved on the Virginia Class. Other benefits include adding variety to the work, which significantly improves workers' morale, and a higher appreciation by multi-trade personnel for the other disciplines in the ship construction process.

Process Reengineering

Electric Boat Corporation, Quonset Point Facility created a process engineering group to specifically improve performance in manufacturing and modular construction. The group's scope includes design and engineering, material management, material control, planning, operations, facilities, and quality assurance.

At the outset of the Virginia Class submarine program, Electric Boat Corporation, Quonset Point Facility (EBQP) relied heavily on experienced personnel skilled in modular construction techniques, to plan detailed manufacturing and assembly operations. Lessons learned during that early phase indicated that further improvements might be achieved by revisiting many accepted practices. In 2002, EBQP created a Process Engineering Group to reengineer current processes with a specific objective of improving performance in manufacturing and modular construction. This group received a broad scope that included design and engineering, material management, material control, planning, operations, facilities, and quality assurance.

The process reengineering effort incorporates lean manufacturing and process modeling techniques. Key to the success is the formation of teams of personnel from directly affected and supporting functions with subject matter experts and facilitators. Prior to any team session, the affected department

managers agree on the mission, specific objectives, strategy for proceeding, and metrics to baseline the process and measure success. Process engineers are assigned to help facilitate the process. The team is then selected, trained, and tasked to map and document the "as is" process, identifying any non-value-added elements for elimination. The team then uses brainstorming sessions, problem solving, simulations, engineering analysis, and other techniques to confirm the validity of the retained elements. Alternatives are proposed and their potential benefits assessed. At the conclusion of the study, an implementation plan is developed, evaluated, and approved.

Specific projects were accomplished that addressed fast flow (or relatively quick jobs), and the significantly larger outfitting of the Command and Control System Module (CCSM). Alternatives that included material control, facilities, tools, fixtures, work platforms, office areas, and tool cribs were considered and implemented. Improvements were documented in construction time, labor cost, and efficient modular construction.

The generic process has shown the benefits of a structured problem-solving approach. The team approach has also improved communications and planning efficiency. Team dynamics have demonstrated the propensity to identify follow-on improvement projects that bring previously unrecognized benefits.

Respiratory Protection Program

Electric Boat Corporation, Quonset Point Facility consolidated its air-fed respiratory program under the direction of the Fire Marshal's Office. A disciplined, proactive approach has produced excellent results with improved employee involvement, competence, and confidence.

Traditional implementation and enforcement of the respiratory Program were left to individual supervisors. Fit testing was administered by the Safety Department, cleaning and distribution was performed by Security, and inventory control was performed by Production Support. This approach had no standardized, formal process and lacked standard sanitary and quality conditions across the shipyard's large respirator inventory (Figure 2-12). Electric Boat Corporation, Quonset Point Facility (EBQP) completely revamped its respiratory pro-

tection program. Changes include expanded instruction, detailed standardized procedures, and the establishment of respiratory checks and reviews to ensure employees' health and safety. EBQP is committed to maintaining the integrity and reliability of its air-fed respiratory systems, together with associated employee confidence and competence. Training methods stress the potential dangers with a direct "no nonsense" approach.

Implementation, enforcement, fit testing, cleaning and distribution, and inventory control were traditionally separate, but are now consolidated within the centralized Fire Marshal's Office. This action recognized that separate efforts did not efficiently address respiratory system requirements. EBQP also ensured that employee confidence and competence were proactively addressed by means of this centralization. Rigorous inspection, cleaning, storage, and distribution provisions were provided as part of this program.

Fully cross-trained, multi-functional Fire and Safety Technicians conduct the training and confirm correct deployment of the air-fed respiratory equipment in the workplace before it is used. They also randomly monitor actual equipment use throughout the facility to ensure proper respiratory system use and functioning. Employees recognize that the Fire and Safety Technicians provide instruction for the program and actively share their

concerns, frequently working side-by-side with them in the tanks. Employees also know that the Fire and Safety Technicians would be called on to effect confined space and medical rescue, if needed. This reality ensures that both parties recognize and cooperate to avoid or eliminate potential dangers. Employees now understand and appreciate that one source will answer any and all respiratory questions. Those answers increase employee training, competence, and confidence, while creating improved safety consciousness and safety results. Prevention has become practice, with no respiratory accidents since this consolidation.

Safety Recognition Program

Electric Boat Corporation, Quonset Point Facility's Safety Recognition Program takes a two-pronged approach to safety. Both the monetary awards and the activity-based awards have proven successful in recognizing employees for excellence in safety and heightening safety awareness throughout the facility.

To ensure a safe work environment for all team members, Electric Boat Corporation, Quonset Point Facility (EBQP) established a Safety Recognition Program based on the following principles: safety is a first priority; safety of the workforce has a direct

impact on the quality and delivery of the product; and attaining and maintaining a good safety record is always a goal the company strives to achieve. EBQP's two-pronged approach to the Safety Recognition program includes monetary awards and activity-based recognition. This approach allows supervision and the hourly workforce to approach safety from different angles. Monetary awards are presented at year-end based on the facility's Lost Workday Injury Rate (LWIR). The formula used to calculate the rate is based on $LWIR = (\# \text{ of incidents} \times 200,000) / \text{production hours}$. (Note: The use of 200,000 gives a rate equivalent to lost workdays per 100 full-

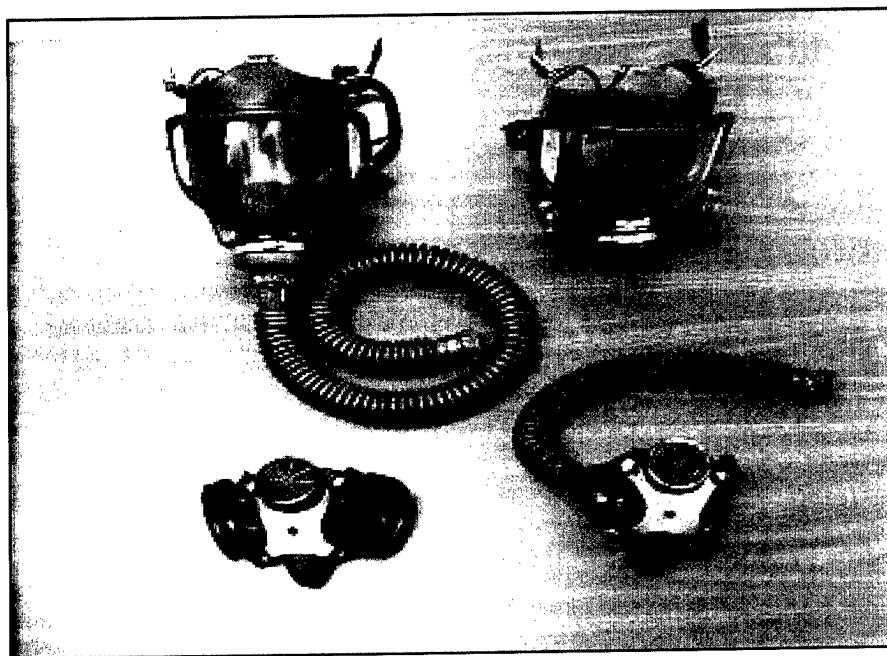


Figure 2-12. Respirator Samples

time employees.) The 2003 LWIR goal for the facility is 3.8. Each team member will be awarded \$150 if the 2003 goal is met.

As part of the 2003 Safety Recognition Program, EBQP is adding several activities-based components to the program to augment and rouse employee interest:

- Safety Quiz consists of a question distributed to employees each week. Employees return answers to the communications office and are awarded a free ice cream coupon for a correct answer. An average of 350 answers is received each week.
- EB Bucks or Safety Dollars are given by supervision to reward significant safety achievements by members of their team and can be redeemed at the facility's cafeteria or the company's Fairwater Store.
- Safety Recognition Awards are used to recognize team members who have completed five or 10 years of service with no recordable injuries. A \$25 Fairwater Store credit is awarded for this achievement.

Team members actively support each aspect of the Safety Recognition Program. While the end-of-the-year monetary award serves one purpose, the activities-based awards have been equally successful in providing immediate reward. At the same time, heightened safety awareness has resulted throughout the facility.

Vanpool Program

Electric Boat Corporation, Quonset Point Facility's Vanpool Program proved to be a highly valuable resource to the company, participating employees, local communities, regional transportation authorities, and the Federal Government. The program's attributes include sustainable cost control, demand growth and expansions, near 100% reliability, and great flexibility.

Electric Boat Corporation, Quonset Point Facility (EBQP) instituted its Vanpool Program in 1980 when the workforce increased to almost 5,000. Other organizations had begun using the adjacent

facilities on Quonset Point, limiting EBQP's parking capacity. A heightened sensitivity to caring for the environment and an energy crises were also occurring. In response to these conditions, EBQP established "QuonseTrans," a non-profit operation made possible through special Federal and State incentives to acquire vans and operate them in an affordable, long-term arrangement. The program's objectives were to reduce commuting costs for the general workforce and extend the company's recruiting area by enticing potential workers from further distances with the benefit of the Vanpool Program. At the height of the program, QuonseTrans was serving almost 500 employees; however, during the 1990s, a dramatic downsizing in workforce reduced the number of employees served to 126.

A major attribute of the Vanpool Program is an interest-free loan to finance the vans. The loan is offered with the Rhode Island Department of Transportation from the Federal Highway Administration, and is a 48-month loan with extended warranties covering an extra five years or 90,000 miles beyond the normal 100,000 miles accrued during the loan's term. The vans are purchased from a local dealer offering the lowest of three bids, and the price is further reduced if a fleet is purchased (between 10 to 20 vans). The current cost to employees is \$15 per week for a rider seat and \$10 per week for a driver seat, plus fuel costs. Since the Vanpool Program began, the rider/driver costs have increased only three times. Drivers are screened for good driving records and checked by on-site physicians for health conditions that could increase risk. The vans and riders are insured through a blanket policy that covers all vehicles operated by EBQP. A long-term relationship with a local towing and maintenance company keeps the vans available for service nearly 100% of the time, and loaner vans are furnished when necessary. The program is currently serving more than 150 employees with 20 vans.

EBQP's Vanpool Program includes Federal income tax deferrals for participants to cover their fees. The service is safe, reliable, offers a friendly commuting service, and has helped reduce highway congestion, pollution, and commuting time.

Section 3

Information

Production

Automated Weld Process Statusing System

Electric Boat Corporation, Quonset Point Facility has moved from a manual, hand-written paper system which provides instructions for weld activities to the development of an integrated software suite of applications for the full management and scheduling of all weld operations in submarine manufacture. A specific tool of the software suite is the Automated Weld Process Statusing System, an invaluable resource in improving productivity and awareness for all welding personnel and management.

Electric Boat Corporation, Quonset Point Facility (EBQP) established an Automated Weld Process Statusing System (AWPSS) to improve welding operations for the manufacture of submarines. This system has been integrated into a suite of software packages for reporting, tracking, and scheduling of all operations associated with welding. The AWPSS system was specifically developed by EBQP to address and eliminate the inefficiencies of a hand-written, paper documentation/tracking system for weld processing.

Prior to AWPSS, instructions for welding were performed by a manual process known as the "Chit" system. Small, colored-coded forms ("Chit sheets") indicating material type to be welded were written by the supervisor to direct the welding operator. The supervisor was responsible for researching data to ensure that the operator was qualified for the operation, determining the proper weld procedure, and verifying the selection of weld wire. Since this task was done daily for many weld operators in each working shift, the assignment of work to the operators became a time-consuming, complex task which easily introduced human error into the process.

Continuous improvement activity at EBQP led to the AWPSS system. This system greatly reduced the margin of error in obtaining the requisite information to perform all weld activity. The manual writing of "Chits" has been eliminated and replaced with computer-prompted forms from a database for weld procedures, specifications, and operator quali-

fications. The system readily provides the weld operator a job ticket with all applicable parameters to complete the weld operation. Also, the supervisor can choose from a variety of approved weld techniques, processes, positions, and fill wire type for each weld joint to either match operator qualification or optimize quality and performance. Since the inception of the system, welding quality has improved, and preparation time for welding has decreased from two hours to five minutes. The AWPSS has been the cornerstone of EBQP's Weld Quality Accountability model of operation.

Drill Exchange System

Through its Drill Exchange System, Electric Boat Corporation, Quonset Point Facility demonstrated that process improvements, such as making material readily available and using outside sources, can result in cost savings and improved performance.

As the work mix changed, Electric Boat Corporation, Quonset Point Facility's (EBQP's) machine shop was confronted with the problem of allocating sufficient equipment and personnel to perform the task of re-sharpening drills. Buying new drills was not a solution because of tightened budget constraints. In-house sharpening capabilities included only two outdated pieces of equipment, and machinists frequently waited in line to exchange their dull drills for re-sharpened or new ones. This process of exchanging drills resulted in many hours of non-productive labor. To address this problem, the machine shop established a process improvement team. The team recommended that sharpened bits be openly available to all machinists from a centrally-located rack. Open access to the rack eliminated the need for the machinists to wait in long lines to interface with tool crib personnel. The rack was organized so various drill bit sizes were sorted and marked, and a collection box was available for depositing dull drills. The team also recommended investigating the use of an outside source to re-sharpen dull drills. The vendor would need to re-sharpen the drills cost-effectively to tight standards, with quick turn-around times to support production requirements.

Sample drills were sent to a potential vendor who returned re-sharpened drills that satisfied EBQP's requirements. The quality of the re-sharpened drills allows EBQP to get longer tool life, better quality, and higher speeds and feeds in all materials. Initially, the new process saved approximately \$5,000 through reduced procurement, saved labor cost with the elimination of non-productive hours, and improved tool performance.

Improved Quality and Flatness of Deck Assemblies

Electric Boat Corporation, Quonset Point Facility implemented standardized procedures and sequencing for the fabrication of deck assemblies for nuclear submarines. As a result of these process improvements, deck flatness improved and length/width distortions have been minimized. The company's new approach to deck structures minimizes the use of secondary processes, reduces overall costs, and improves the quality of the deck structure.

Electric Boat Corporation, Quonset Point Facility (EBQP) utilized multiple shop groups led by different foreman to construct decks and platforms for nuclear submarines. This process entailed many steps: first, the structure was assembled on a platen to design dimensions; strong backs were installed and cross braces were added; the first side was welded, the strong backs were released, the deck was flipped, and the strong backs were re-secured; next, the second side was welded and the plating was attached. While some decks are readily assembled, others (i.e., upper level engine room decks) require complex planning and sequencing. Each group set its own procedures and did its own planning. As a result, EBQP encountered problems due to variations in the final products. Of specific concern were variations in distortion, flatness, and shrinkage. The distortion tolerance for length and width of a deck platform approximately 35' x 24' is ± 0.300 ", and flatness is held to ± 0.500 ". Although strong backs were used, the flatness of a deck fabricated by multiple teams could vary three to four times from tolerance. Consequently, secondary processes such as flame straightening or hot pressing were routinely used. These secondary processes increased production cost and often induced unintended bowing and compounded shrinkage problems. Additionally, decks were constructed to the

exact, final dimensions called for in the design. Unfortunately, extensive welding operations tended to lead to deck shrinkage beyond acceptable boundaries. If the deck was shrunk too much, it needed to be cut in half, spread, and re-welded.

In preparation for construction of the Virginia Class, EBQP implemented a Design/Build process improvement, recognizing that dimensional control was more critical for the Virginia Class because all decks float on 50,000 lb. mounts and do not touch the pressure hull. As a result, length/width discrepancies cannot be corrected by cutting and welding to the hull. A team of engineers, technical experts in structural design, and the shop foreman were assembled to determine how best to optimize and standardize the assembly sequence for deck structure. The team resolved that only one foreman supervise all work for each major deck assembly, which immediately eliminated variation due to different procedures and planning. Weld shrinkage was built into the initial fit by using design tools to determine an appropriate amount of spread in the assembly to achieve final dimensions equivalent to design. The foreman also agreed to spread welders across the deck to dissipate heat and further reduce possible shrinkage. Fabrication teams can build the deck in prefabricated assemblies that are then welded together. A new standardized fabrication sequence was established with the fabrication team using photogrammetry to ensure that platens are flat and/or shimmed to create surface flatness; the prefabricated deck assemblies and I-beams (fabricated in-house by EBQP) are fit-up on the platen; the first side of the structure is welded, a one-inch reverse bow strong-back is attached to the structure from forward to aft down the center line, and the assembly is flipped 180° and cranked down onto the platen to incorporate a camber (essentially breaking the back of the structure); then the second side is completely welded, the deck plates are added and welded, and finally the structure is checked for flatness and dimensional tolerance.

EBQP found that these new procedures improved deck flatness, controlled dimensional tolerance, and reduced fabrication time. First-time quality is achievable, as secondary processes such as pressing and flame spraying have been eliminated on large deck structures. EBQP compared engine room deck construction time from SSN774 to SSN776 and found that cycle time had been reduced by three months or 23%.

Pipe Marking, Cutting, and Bending

Electric Boat Corporation, Quonset Point Facility automated its pipe marking, cutting, and bending processes by implementing Direct Numerical Control and Computer Numerical Control systems. These systems enable the company to increase product quality, decrease staff requirements, and reduce turnaround time.

Electric Boat Corporation, Quonset Point Facility (EBQP) automated its pipe marking, cutting, and bending processes into a streamlined operation by implementing Direct Numerical Control (DNC) marking, cutting, and bending machines. Automated pipe marking and cutting use a single, custom-built machine supplied by Dante Precision, with a customized Human Machine Interface. The automated pipe bending machines are DNC Swartz-Wirtz CNC40, 60, 100, 265 benders that strictly perform cold bending for pipes with diameters ranging from ¼" to 10". All machines are part of an ethernet network that automatically downloads up-to-date pipe design data at regular intervals during the day.

The U.S. Navy has extensive requirements for pipe marking on nuclear submarines. Pipes must be permanently marked with at least 10 sets of information to establish a pedigree for every piece installed. Previously, pipe-marking operations were performed manually using "vibro-etching" tools. EBQP devoted 10 individuals working up to three shifts per day to manage this operation. The manual transcription of data from drawings to pipe was error prone, and markings were often difficult to read, and the risks of injuries (cutting and repetitive motion strains) were high. An additional eight to 10 mechanics performed cutting operations, requiring review of design drawings, manual layouts of bend lines and cutting measurements, and cutting to prescribed lengths. Cutting accuracy was held to ± 0.2 ", but true accuracy rested with the mechanic as mark interpretation was subject to human error.

Pipe bending was accomplished by manual entry of bending information into the machine controller. Operators reviewed requirements from the bend data sheet, part of the drawing package. While the bend data sheet called out the necessary bend angles, it did not provide the operator with information on the degree to which the machine should over-bend the pipe. Over-bends are necessary because pipes will "spring-back" to some extent. Spring-backs vary by material type, bend angle, and pipe diameter. Op-

erators were required to have enough experience and knowledge of spring-back amounts to perform manual over-bend calculations; therefore, they could not enter the bend angles from the bend data sheet, but had to correct for spring-back and radial growth on a pipe-by-pipe basis, making transcription and over-bend calculation errors an issue.

Automation of the marking and cutting operation resulted in reduced labor (from 10 operators to one operator per shift), thus reducing process time for individual operations from 15 minutes to four minutes per pipe detail, and accomplished in two shifts instead of three depending on volume. Marking legibility and transcription errors are no longer a problem since the pipes are stamped in uniform script and the data is automatically sent from design to the marking mechanism. Safety, a high priority at EBQP, increased considerably due to the near elimination of vibration injuries and a 25% reduction in cutting injuries.

Pipe details emerging from the marking/cutting process are loaded into a rack for transportation to the nearby pipe bending stations. As with the marking/cutting system, operators enter a part number into a workstation PC with commercial-off-the-shelf CAD/CAM integration software. All numerical control bending programs necessary to bend all the pipes arriving at each station are automatically distributed. The software is sophisticated to automatically calculate over-bend angles per part and download producibility information (e.g., shop floor and ceiling height limitations) so pipe bending will not be obstructed. EBQP uses four Computer Numerical Control (CNC) machines for pipe bending. The CNC machines can produce bends of two-, three-, or five-times a pipe's diameter in pipes with diameters of 0.250" to 10.000" with varying wall thicknesses. Because there may be up to 22 bends per pipe detail, EBQP's CNC machines use an automated power boost and mandrels to minimize wall thinning. The software also manages the timeliness of data, regularly expunging old design information from the system.

Quonset Point Nuclear Pipe Shop

Electric Boat Corporation, Quonset Point Facility continues to meet the needs of the "Nuclear Navy" by enhancing the operations of its Nuclear Pipe Shop. Shop facilities and fabrication operations for piping systems have been improved by new and innovative methods of process control with in-shop training/communication, enhanced cleaning methods, and weld process control through automation.

As the "Nuclear Navy" was being established, it was quickly recognized that stringent requirements would be placed on materials and welded components for nuclear submarines. Key to the operation of nuclear submarines is the piping systems installed throughout the ship. Electric Boat Corporation, Quonset Point Facility (EBQP) understood the need for improved pipe fabrication and established a Nuclear Pipe Shop in 1978. The shop was set up to be autonomous, providing maximum efficiency in the fabrication and testing of nuclear piping assemblies and components. As such, the shop was often referred to by management and the Navy as the model for other manufacturing facilities to follow. Over time, other EBQP shops adapted the Nuclear Pipe Shop model to perform their fabrication activities.

In May 2002, the Nuclear Pipe Shop was relocated to a newly refurbished shop on site. EBQP, as part of its commitment to continuous improvement, ensured that the new facility implemented the latest process improvements. The new shop promotes better material flow, material control, and cleanliness by restricting access to the enclosed shop area. For pipe fabrication, the material is received into the shop, processed, cleaned, fabricated, inspected, packaged and shipped directly from the shop. Only limited work (e.g., radiography, test, and bend operations) is performed outside of the shop. Enhancements within the new shop include:

- **Computer Kiosk Station:** Provided for all personnel in the shop and used to access current work instructions/procedures, training videos, and work status.
- **Environment Control:** Used to control the volume of air recycled to a minimum of ten times per hour. The compressed air is filtered to eliminate contamination that can be detrimental to nuclear piping systems and components. The argon system for welding is continuously monitored for acceptable dew point levels of moisture and oxygen.
- **Pipe Cleaning:** The traditional method was performed by soaking a lint-free cloth with solvent and pulling it through the pipe with an attached nylon lanyard, a difficult process requiring an average of 15 minutes per pipe assembly to perform. EBQP's innovative approach to cleaning the internal diameter of piping is now performed by forcing a foam plug soaked with an approved solvent through the pipe with filtered, compressed

air. This approach produced superior results in less than 20% of the time (three minutes).

- **Pipe Welding:** Performed by gas tungsten arc welding (GTAW), achieved by manual or automated modes, in accordance to NAVSHIPS 250-1500-1 and MIL-STD-278. Sixty percent of the welding is performed by automation using either horizontal rolled or orbital welding equipment. New state-of-the-art orbital arc welding equipment is being implemented for pipe welding using a system from Arc Machines, Inc., which includes data acquisition of the arc welding process to improve process control and quality.

Simultaneous Machine Shop Operation

Electric Boat Corporation, Quonset Point Facility's Simultaneous Machine Shop Operation uses either two Computer Numerical Control machines, or one Computer Numerical Control machine and a manual machine, or two manual machines. Significant cost savings have been realized using any of these combinations.

Previously, each operator in Electric Boat Corporation, Quonset Point Facility's (EBQP's) Machine Shop set up and ran only one machine at a time. For long-run jobs, an operator's idle time was not used productively. The average lot size was four pieces with numerous one-and two-piece jobs. To address operators' idle time, EBQP implemented a Simultaneous Operation for its Machine Shop as a cost reduction measure. Simultaneous Operation is two machines engaged concurrently in either an operating/operating or a set-up/operating mode.

Initially, Simultaneous Operation was tested over a 60-day trial period, and once proven effective, was incorporated into EBQP's procedures. As an incentive, an additional \$2 per hour was given to employees who ran concurrent machines. A unique code in the Automatic Time and Attendance (AT&A) System authorizes payment of the while-engaged premium rate. EBQP's Computer Numerical Control (CNC) machines are located face-to-face to accommodate operator access while running concurrent machines.

To assist the operators, tool wear was calculated and tool change points were included in the program to reduce the chance of broken or worn tools or defective parts. On average, 50 machinists processing 10% of the overall workload are qualified to

use Simultaneous Operation. On average, 385 labor hours per week or approximately 17,000 hours per year are spent using Simultaneous Operation, which has resulted in a 4.7% reduction in Machine Shop labor hours.

Standardized Tool Program

Electric Boat Corporation, Quonset Point Facility's Standardized Tool Program greatly reduced the number of carbide insert tools, procurement costs, and labor by decreasing machine operators' time spent searching through numerous tooling that previously existed.

Throughout the years, Electric Boat Corporation, Quonset Point Facility (EBQP) had accumulated numerous carbide insert cutters from many different tooling vendors. Although many of these cutters could be used for the same application, they required different carbide inserts, shims, locking pins, seat and screws. To reduce the inventory of dissimilar hardware and carbide inserts, EBQP implemented a Standardized Tool Program. A cross-functional Tooling Team was established, comprised of personnel from industrial engineering, supervision, machinists, methods, Numerical Control (NC) Programming, suppliers, and stockroom.

The Tooling Team chose Kennametal as its prime tooling vendor. Kennametal was well established in the U.S. and its top-notch threading and grooming systems were already in use. The company offered a number of proven and versatile grades, and its drilling system is known to be the best in the industry. Kennametal's track record of technical support was outstanding, and the company offered a flexible and lucrative cutter exchange program, giving free cutters if enough inserts were purchased. Prior to doing business with Kennametal, EBQP had 677 different types of inserts in inventory for the various types of cutters used. Since implementing its Standardized Tool Program and selecting Kennametal as its prime tooling vendor, EBQP has realized a 49% reduction in different types of inserts and a 64% reduction in carbide insert drills.

Twin Head Welding Process

With the implementation of its Twin Head Welding Process, Electric Boat Corporation, Quonset

Point Facility transformed a manual operation that resulted in operator fatigue and low productivity to a mechanized process that significantly increased productivity.

Traditionally, adapter rings were welded to spherical air flask bodies using the gas metal arc welding process where welders manually held the welding torch in place for long periods of time. The torch was held in one position while the heated flask, with the adapter ring tacked in place, was rotated on a turntable past the torch. The fatigue and heat associated with this process were detrimental to productivity, which is measured by the pounds of weld wire deposited per shift. The average weld deposition was 15 to 20 pounds per shift.

To eliminate fatigue and increase productivity, the employees and welding technicians at Electric Boat Corporation, Quonset Point Facility (EBQP) developed a two-headed mechanized spray welding machine using four motorized cross slides and joy sticks. The new two-headed welding machine now allows the welder to perform two welds simultaneously. Two separate rings are welded to the flask at the same time while the operator sits behind a darkened shield and operates the joy stick. The change to a mechanized process reduced span time by 50%, eliminated welder fatigue, improved weld quality, and increased the deposition rate to 60 to 70 pounds per shift.

Vertical Cabling of Submarine Cylinders

Electric Boat Corporation, Quonset Point Facility's modular and vertical hull construction resulted in the ability to run large cables with greater safety and produced extensive savings in labor costs while improving the quality of the finished cable installation.

Previously, cable installations in submarine cylinders at Electric Boat Corporation, Quonset Point Facility (EBQP) was sequenced to precede major structural work, including hot work such as welding and its related heat soaks with consequent potential damage. Although some cables were localized and confined to a particular area of the ship, many of the cable runs supported global services or larger areas of the ship. Thus they required many stops and extensive coiling before completion. The position of the submarine cylinders during assembly was horizontal, or parallel to the ground, and these intermittent cable installations had to be per-

formed in that position. Because of the high cable weights (10 pounds per foot in some cases), the operation was labor intensive and prone to personal injury and damaged cable. Continuous cable runs were accomplished by revisiting the cabling effort as many as three to four times so that cables could be pulled through successive cableways as the assembly of the cylinder progressed and the ways were made available.

A major change to the cabling process was introduced with the inception of modular design for the Virginia Class. The modular design allowed for the splicing of many of the service cables where the cylinders are joined. These splices allow incremental installation of hull length cables as separate pieces at the most convenient point in the construction cycle. Another innovation is the construction of most internal work while the hull section is in a vertical position. The EBQP team took advantage of this and now installs cable while the hull is in this vertical position. This has resulted in reduced labor hours, fewer injuries, and reduced cable damage.

With the use of handling fixtures, cable reels, and a crane, heavy cable can now be installed vertically by dropping the cable down through the hull section using a reduced number of personnel and considerably enhancing safety. When this approach is used, it results in approximately 60% savings in labor costs and reduces installation time by 37%.

Welding Quality Accountability

Electric Boat Corporation, Quonset Point Facility took steps to develop and implement an electronic tracking and reporting system for weld quality accountability. The system, Shipyard Weld Status System, evolved from a hand-written, paper system to a fully-automated management tool for monitoring all aspects of weld operations for fabrication of U.S. Navy submarines.

Typically, each submarine has approximately 300,000 structural welds. Confirming the status of the welds during the construction of the submarine is an arduous task. Electric Boat Corporation, Quonset Point Facility (EBQP) is developing and implementing an electronic tracking and reporting system to confirm that weld operations are complete. The system assures that the weld quality has been verified at each operation in the fabrication process by tracking weld fit-up, welding, back-

gouging, repair, and nondestructive inspection (VT, MT, UT, RT). For compliance to EBQP's SUBSAFE Program, accurate documentation of in-process weld quality is required. The tracking and reporting system also enables EBQP to intelligently schedule and assign work due to the system's ability to have a current and accurate picture of the status of work in progress at all times.

Prior to the electronic system, tracking of the weld process was documented by hand-written documents (Chits) for the issuance of weld wire and the performance of all weld activity, both pre-and post-processing. The information required to prepare the Chits was manually extracted from engineering drawings and hard copy procedure sheets. Weld status information was extracted from a completed Chit, recorded, and maintained as permanent documentation, making this approach time consuming. Research was performed by supervisors for each weld operation to determine the appropriate, qualified weld operator, proper weld procedure, and selection of correct weld filler wire for the job. This was a complex task in which errors were easily introduced to the operations, or the paper Chits became lost or damaged.

EBQP overcame the pitfalls of the Chits system by developing and deploying the Shipyard Weld Status System (SWSS). A unique SWSS record is established for every weld on a ship. The record provides details of the weld joint (e.g., material type and thickness), compatible weld processes and filler wires, and sign-off points for weld operators and inspectors. Continuous improvement activities led to the development of the Automated Weld Process Status System (AWPSS), followed by the Personnel Qualification System and the Electronic Record System (ERS). Each of these data collection systems is integrated electronically to automate and streamline weld operations for selection of weld wire/process procedures, weld operator qualifications, weld specifications, and tracking. The ERS eliminated the previous paper tracking system and allows employees to electronically sign-off (approve) on process routing activities. Safeguards are built into the system which provide constraints to prevent activities from being accomplished out-of-sequence. Rules have been established to validate the authorization(s) of an employee to sign-off on an activity. The ERS terminals require scannable badges that provide unique, secure identification of individuals who are authorized to certify completion of quality operations and/or work status.

By automating and integrating the weld accountability process, EBQP reduced cost and improved schedule performance by eliminating rework and providing a better tool for the coordination of work-in-process. Use of the automated electronic system simplified the weld tracking and quality control process, and dramatically reduced errors in procedural documents to less than 10% compared to the previous Chits system. As a management tool, the SWSS can generate more timely and accurate reports in the overall structural status of a ship under construction.

Facilities

Crane Asset Management Program

Electric Boat Corporation, Quonset Point Facility's establishment of a Crane Asset Management Program resulted in improved equipment utilization and reliability, and in the reduction of labor hours expended for crane maintenance.

When Electric Boat Corporation acquired the Quonset Point Facility from the Navy, the average age of the overhead cranes was 30 years. The cranes were a variety of makes and models and classified as light service. Few cranes had maintenance manuals or repair data, and their maintenance was further hampered by the difficulty in procuring repair parts and Original Equipment Manufacturer service. Overhead cranes, although critical to maintaining the flow of production throughout the manufacturing process, were not well managed.

Electric Boat Corporation, Quonset Point Facility (EBQP) analyzed the management of the cranes and found more than 300 unresolved crane deficiencies (58% of the overhead cranes were operational and the resolution of deficiencies averaged 25 weeks to complete). Determining that changes in crane maintenance and engineering areas were necessary, management consulted outside resources to evaluate the program (including the Navy Crane Center [NCC]). The crane program became an engineered-driven program, and compliance to Occupational Safety and Health Agency (OSHA), American Society of Mechanical Engineers, Crane Association of America, and manufacturers' standards and guidelines were reinforced.

The result of this effort was the creation of a Crane Management Program. Since the initial audits, a

Lifting and Handling Program manual was developed, and all crane records and manuals are centrally managed by the organization. Crane-specific preventive maintenance records and testing documents were developed. Currently 95% of the assets are operational, and open deficiencies have been reduced from 300 to less than 50, proving the program's success.

Employee Designed Work Cells

Electric Boat Corporation, Quonset Point Facility empowered its work teams to collaborate on the design of work cells to improve the efficiency of their areas. This approach led to employees taking ownership for and pride in the work they do and the space in which the work is accomplished.

In 2002, a process improvement team from Electric Boat Corporation, Quonset Point Facility's (EBQP's) Machine Shop Small Assembly area was empowered to redesign their work area. The team was relocating from an existing location within the manufacturing facility which presented the perfect opportunity for the team to improve their current situation where the work area was unorganized, cluttered, and lacked the necessary lighting. The layout of the work area made supervision difficult and increased non-value-added time to gather the necessary tooling to complete the required machining and assembly tasks.

The team, comprised of employees from each of the three shifts, was provided the necessary resources (including Computer Aided Design [CAD] services) enabling the task to be successful. After a series of meetings to discuss workflow and support requirements, CAD mockups were created to lay out the new area. Necessary equipment including workbenches, lighting fixtures, lockers, tooling, and fixturing were acquired, and the work area was completed in accordance with the team's design. The new work area includes special tooling as well as a KANBAN set up for consumable items.

As a result, the new work area provides employees easy access to all the resources required to perform their jobs in a clean, open, and orderly environment. The new area also provides management with visual controls which enable them to easily observe activity within the work cell. The largest factor attributing to the success of the project is the employees' ownership of the design of the workspace. The success of this project has also led

to similar approaches in the design of EBQP's new plate processing center and the re-design of the electrical assembly area. The innovative electrical assembly area incorporates the concepts of ergonomics and modularity.

Environmental Benefits of Oil Skimmers on Coolant Tanks

Electric Boat Corporation, Quonset Point Facility's replacement of its oil skimmers saved potential costs associated with the Rhode Island Department of Environmental Management Agency's findings. The new oil skimmers reduced the need to frequently replace coolant, and improved employees' quality of life by eliminating the formation of bacteria that often causes skin irritation.

Electric Boat Corporation, Quonset Point Facility's (EBQP's) machine coolant supply tanks use oil skimmers to remove tramp oil to extend the coolant's useful life and eliminate anaerobic bacteria growth. The age and condition of the oil skimmers, combined with sporadic maintenance and cleaning of the skimmers, led to an inefficient skimming process. Without an effective means of separating the tramp oil from the coolant, the coolant became rancid and required replacement. EBQP's average coolant cost per month was \$1,700.

EBQP evaluated numerous replacement skimmers based on ease of installation, effectiveness, and durability, and selected and installed a Zebra Belt Skimmer with diverters that separate the oil and coolant, reducing the monthly coolant cost to \$619. EBQP also implemented a maintenance and monitoring program to ensure coolant integrity. EBQP's new oil skimming process is so effective that the Rhode Island Department of Environmental Management determined that the machine coolant tanks would not be categorized as underground storage tanks which are controlled by strict regulations for petroleum and hazardous materials. If EBQP's coolant supply tanks had fallen into this classification, the potential monetary penalty and clean-up costs could have been significant.

Security Access System

Electric Boat Corporation, Quonset Point Facility's upgraded Security Access System increased its con-

trol of access into the facility and movement of personnel within the facility. The flexibility of the system allows the company to be more responsive to change in times of increasing security requirements.

National security is an utmost consideration at Electric Boat Corporation, Quonset Point Facility (EBQP) due to the nature of its business. Great care must be taken in classifying and monitoring clearance levels, and issuing security badges to employees, vendors, and visitors at the facility. On two occasions, EBQP received the Department of Defense's James S. Cogwell Award for outstanding security achievement, making it one of only a few facilities to have earned this honor more than once.

In 2002, EBQP updated its Security Access System to a state-of-the-art system, a stand-alone process with a minimum number of authorized users, which produces badges similar to those issued at Electric Boat Corporation, Groton Facility. To initiate the process, the Security Department enters personal information about the employee into the system (e.g., name, social security number, a unique employee identification number, security clearance level, and a digital image of the employee). The employee's access badge is then encoded with this embedded data in addition to displaying the employee's picture and a color-coded security clearance level indicator on the front of the badge for easy identification. The encoded data allows an employee to access the facility's Automated Time and Attendance System and access through the Automated Access Control System, which provides access through unmanned security gates. Since the badges contain encoded data chips, proximity sensors read the data and allow passage through the gates for authorized personnel. Built-in controls can lock out unauthorized personnel and provide electronic data on employee activity. In times of heightened security requirements, the system can easily be reprogrammed to require that personnel also enter a unique password into the gate sensors along with proximity sensor validation.

The new Security Access System enabled EBQP to better utilize its security forces to provide physical security in areas other than access gates. The upgraded system provides decreased badge processing time, standardization with the Groton facility's security system, and the flexibility to make changes in the future.

Management

Behavior Observation Awareness Team

Electric Boat Corporation, Quonset Point Facility's Behavior Observation Awareness Team represents members of the hourly workforce from all shifts and departments whose main purpose is to assist the Safety Department in creating and maintaining a safe work environment.

The possibility that assigned safety professionals can witness all safety-related activities at a large facility is low. To control this situation, Electric Boat Corporation, Quonset Point Facility formed the Behavior Observation Awareness Team (BOAT). The team represents members of the hourly workforce from all shifts and departments, and is responsible for assisting EBQP's Safety Department and their own departments in creating a safe work environment. The BOAT also assists in incident identification, accident avoidance, workplace safety inspections, enforcing safety rules and regulations, and intervention when observing unsafe work habits or situations.

The BOAT meets weekly with Safety Department personnel to report findings from the following week, share lessons learned and ideas on how to practice better safety, review action items from previous team meetings, and receive bi-weekly training on a variety of safety topics. EBQP's BOAT serves as the "eyes and ears" of the facility and fosters a team atmosphere and ownership in creating and maintaining a safe work environment.

Build Sequence Work Package

Electric Boat Corporation, Quonset Point Facility's Build Sequence Work Package is a documented approach for capturing the optimum sequence to manufacture a highly complex assembly using an Electronic Product Model and associated three-dimensional views to develop a detailed assembly sequence at the part level, taking into account the maximum amount of subassembly, maximum welding mechanization, maximum utilization of automated layout marking, and minimum material handling.

Electric Boat Corporation, Quonset Point Facility's (EBQP's) latest advances in manufacturing technology are embodied in its Build Sequence Work Pack-

age (BSWP). BSWP is a documented approach for capturing the optimum sequence to manufacture a highly complex assembly utilizing the Electronic Product Model. EBQP personnel use this model and associated three-dimensional views to develop a detailed assembly sequence at the part level, taking into account the maximum amount of subassembly, maximum welding mechanization, maximum utilization of automated layout marking, and minimum material handling.

Building a highly complex assembly such as a submarine that contains thousands of subassemblies, parts, and operations is a challenging task. The traditional approach employed the use of hard-copy drawings and data as the primary vehicle to provide technical requirements and trade instructions to the mechanics on the deck plates. Drawings were difficult to read and interpret, and often required several drawings to obtain the full scope of work. Accessing drawings, work instructions, technical data, and other relevant information was time consuming and required access to multiple drawings and frequent use of a database containing pertinent information. EBQP discovered that some of its new personnel did not have the background to quickly adapt. Because of EBQP's Advanced Manufacturing Technology program, the traditional approach was questioned. The company realized it needed to provide trade supervision and mechanics with an improved tool to aid in the understanding of the scope of work represented by the drawings, and customize manufacturing aids that enable a mechanic to spend minimum time understanding the drawing and technical requirements. Mechanics were spending about 15% of their time following the traditional process and not adding value to the product. EBQP recognized the need for a single, comprehensive, user-friendly manufacturing aid that would provide all information to the trades needed to complete a given unit.

In response to that need, EBQP is in the process of providing manufacturing aids in the form of isometric views that will present the technical requirements, work sequence, trade instructions, and accurate control requirements in a clear and concise manner. Technical requirements are pulled down from CATIA design models to include part numbers, isometric views, drawing details, critical dimensions, and applicable notes. The work sequence depicts the order of structural assembly, scope of subassemblies, sequence numbers, and exploded views when required. Trade instructions include critical dimensions, fixture requirements, joint design and identities, length of welds, and key views. The entire process is accom-

plished by a multi-discipline team that includes representatives from Operations, Process Engineering, Accuracy Control, and Planning and Production Control. The result of these efforts is the consolidation of all manufacturing documents and requirements into a single, user-friendly BSWP that provides complete, detailed instructions and pictorial sequences for the step-by-step fabrication of the unit.

When fully implemented, the BSWP will significantly reduce the complexity of interpreting drawing and technical requirements, while providing pre-planned manufacturing sequences. The process will eliminate the need for multiple drawings, and is anticipated to eliminate 15% non-value-added work per tradesman.

Comprehensive Industrial Safety Program

Electric Boat Corporation, Quonset Point Facility developed and implemented a comprehensive industrial safety program that actively involves

all employees. The program educates employees on all aspects of safety and empowers them to create and maintain a safe work environment. Injury rates have been reduced by 86% since the program's implementation.

Electric Boat Corporation, Quonset Point Facility's (EBQP's) Industrial Safety Program is more than a managed system of safety policies, procedures, and training. The Comprehensive Industrial Safety Program is a proactive approach to safety that strives to involve every member of EBQP's workforce. The program was developed to minimize hazards in the workplace, reduce accidents resulting in lower employee injury rate, reduce Workers' Compensation claims, and help employees quickly identify and correct unsafe conditions that may occur in their work environment. Key to the success of the program is EBQP management's commitment to safety.

In conjunction with its policies and procedures, EBQP conducts training to help employees improve their work practices and enhance performance.

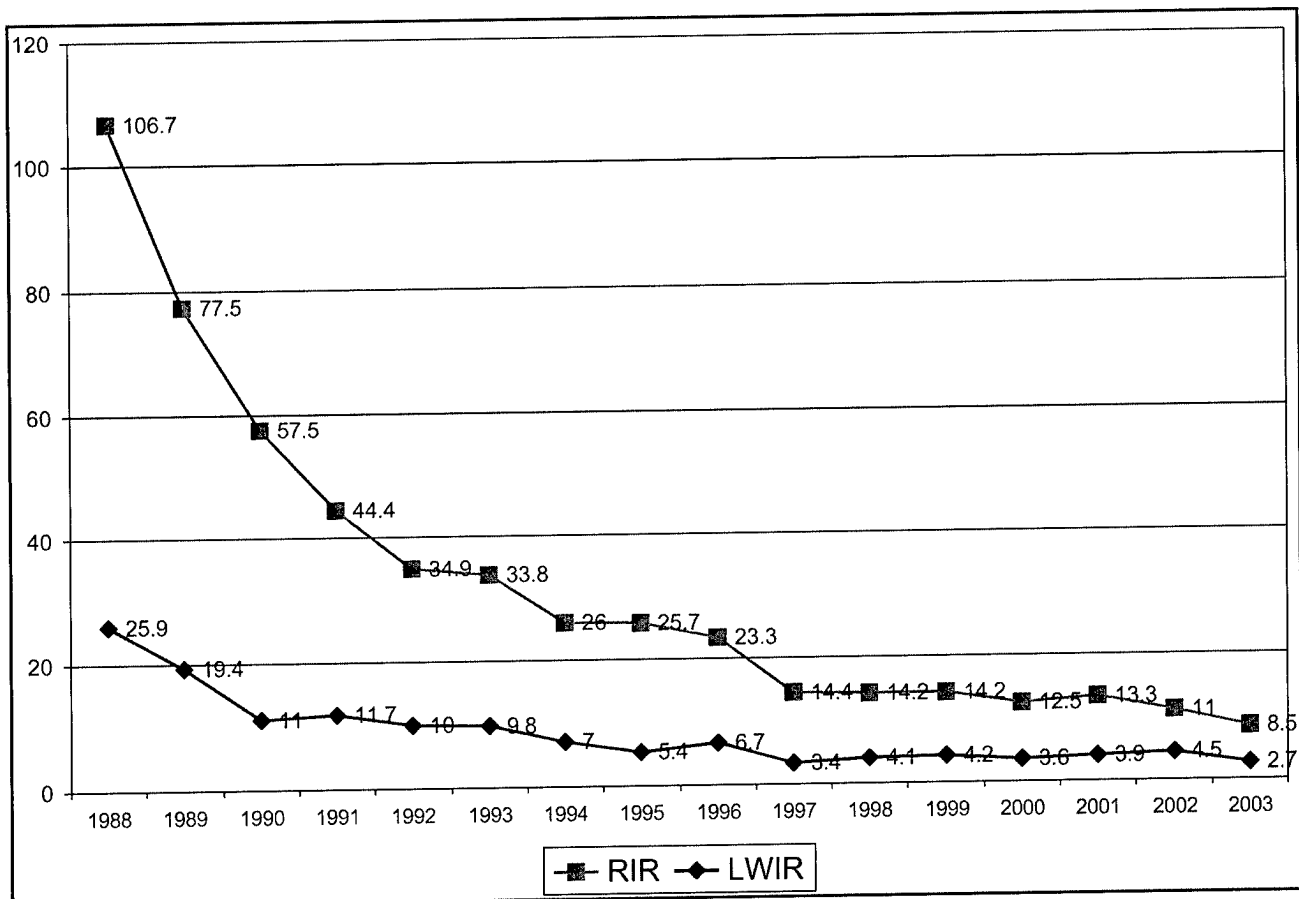


Figure 3-1. RIR/LWIR History

Other resources available to employees include Safety Advisors who provide guidance on safety matters; Shipyard Standard Procedures which provide direction to complete tasks in a safe manner; and Standard Procedures to handle hazardous situations, perform audits, and inform employees of the latest Occupational Safety and Health Administration (OSHA) regulations. Safety Manuals are also available and accessible by all departments electronically through Lotus Notes. The company uses OSHA training sessions to educate employees on OSHA requirements to assist them in identifying possible safety concerns and what they mean to EBQP.

The Safety Matrix is another tool which plays a role in EBQP's safety program. A checklist is used to identify the most frequent types of safety violations within the facility. This information is used weekly by a team leader who is selected by the area supervisor. The team leader conducts a safety audit of his/her work area, and promotes the active participation of all team members in the safety, health, and welfare of co-workers. Another component of EBQP's safety program is the Weekly Supervisor Safety Forum which is designed to facilitate open and honest communication between supervisors and the Safety Department. Meeting topics often include a review of all reported injuries, accidents, and near misses, an exchange of lessons learned, safety recommendations, and the presentation of general awareness information. Supervisors are encouraged to bring back questions and concerns from team members and communicate the information to team members.

To further strengthen the program, EBQP conducts weekly safety audits during which photographs are taken of unsafe conditions or noteworthy safety compliance. This information is shared at the Weekly Supervisors Forum and necessary stand-down meetings. Since communication is critical to the success of the safety program, safety issues are communicated to all work areas through several means including Weekly Information Bulletin, Target Vision, Centerline, All Team Notes, and Lotus Notes.

By continuously educating employees on all aspects of safety and empowering them to participate in the creation and maintenance of a safe working environment, injury rates have been reduced by 86% since implementation of the program in 1988 (see Figure 3-1), proving EBQP's success with its Comprehensive Industrial Safety Program.

Employee Assistance Program

Electric Boat Corporation, Quonset Point Facility values the well-being of its employees, and implemented an employee assistance program that provides the necessary resources to handle personal or family-related hardships.

Electric Boat Corporation, Quonset Point Facility (EBQP) provides a comprehensive employee assistance program for its employees and their dependents. The program, Optum Care 24, is administered by the United Healthcare Corporation as part of the company's healthcare plan, and provides assistance 24 hours a day, seven days a week.

Optum Care 24 addresses all aspects of health and well being, and provides accessibility to information and resources for almost any problem. Employees access the services by calling a toll-free number. Trained counselors and nurses are available to help with a wide range of issues such as relationships and family troubles, physical health concerns, substance abuse, chronic health ailments, minor medical emergencies, financial concerns, work-related stress, questions about medication, and personal legal problems. These counseling services are private and held in strict confidence between the counselor and the client. The program is voluntary except in cases of substance abuse or psychological problems affecting an employee's work performance. In these situations, the company may require the employee to participate in the program. The first seven counseling sessions are free; any additional sessions are covered under the employee's healthcare plan. As part of the counseling services, clients receive additional information and in-depth education as needed.

Optum Care 24 offers a wide range of information and helps clients develop a plan of action. For assistance beyond what the program can provide, clients are referred to an appropriate resource. Regular follow-up sessions are also conducted to ensure that clients are getting the help they need. Another feature of Optum Care 24 is the audiotape Health Information Library, where employees call the same toll-free number and select topics from more than 350 recorded health messages. This same information can also be faxed. Based on the positive feedback from its employees, EBQP's Employee Assistance Program is considered to be a valuable service.

Lean Manufacturing Training

Electric Boat Corporation, Quonset Point Facility's supervisors, multi-trade apprentices, and other key personnel attended an eight-hour Lean Manufacturing class. The company also developed a partnership program with the Community College of Rhode Island and the Rhode Island Manufacturing Extension Services to create a Lean Manufacturing Certification program.

Lean Manufacturing is the systematic approach of identifying and eliminating waste through continuous improvement techniques. A Lean enterprise is more productive with existing resources by eliminating non-value-added activities. To take full advantage of Lean Manufacturing concepts, the entire enterprise should be involved, from top management to the tradesman. However, involvement begins with a solid foundation and understanding of the principles of Lean Manufacturing.

To help management "buy-in" to this concept, Electric Boat Corporation, Quonset Point Facility's (EBQP's) 140 supervisors, approximately 50 multi-trade apprentices, and other key personnel attended an eight-hour Lean Manufacturing class. During class, attendees learned how to control work-in-process bottlenecks, lead a change initiative, identify and reduce non-value-added work, and implement and manage the manufacturing flow process. To further its efforts, EBQP developed a partnership program with the Community College of Rhode Island (CCRI) and the Rhode Island Manufacturing Extension Services (RIMES) to create a Lean Manufacturing Certification program, a 12 to 15 credit program featuring details of the Lean Manufacturing philosophy and a variety of complementary educational tools. The RIMES Lean Training courseware includes Lean 101, Value Stream Mapping, 5S Systems, Pull/Kanban, and Set-up Reduction. Before taking the Lean Training classes, each person is required to complete or test out of CCRI courses in Fundamentals in Writing, Elementary Algebra, Seminar of Student Success, and Workplace Relationship Skills.

With top management's dedication, the training and application of Lean concepts is well underway, with the plan being 100% participation by the entire workforce. EBQP is building a solid foundation and understanding of lean concepts. In 2003, nine Lean projects were initiated and one was completed, resulting in savings of \$11K.

Multi-Purpose Security Facility

Electric Boat Corporation, Quonset Point Facility's Multi-Purpose Security Facility includes total site surveillance and visitor access control in a single location. The Multi-Purpose Security Facility operates 24 hours a day, seven days a week and is equipped with state-of-the-art hardware and software.

Electric Boat Corporation, Quonset Point Facility (EBQP) has begun a major capital improvement of its security systems, policies, and procedures. The previous system was supported with a minimal budget until the events of September 11, 2001. Visitors entered EBQP and were taken to an internal badge office. This method created a high-risk situation for both the shipyard and the visitor. No surveillance equipment or procedures, other than direct eye contact, were available. During non-core operating hours, EBQP's security workforce operated out of a single location with reduced staff.

EBQP's main objective for its new Multi-Purpose Security Facility is to increase the control of visitors entering the facility. All visitors now report directly to the new Visitor/Badge Control Center where they obtain badges and are briefed before entering the facility. The technology incorporated into the new visitor and employee badge systems provides greater control at entry points, and reduced unnecessary activities that could cause traffic congestion and impede access. A conference area with audio-visual capabilities was added to conduct hearings and meetings and accommodate those events when perimeter access is an issue. The conference area has eliminated unnecessary entry into the facility by visitors or vendors who do not need to enter the complex or may be considered a potential security risk.

With EBQP's new Multi-Purpose Security Facility, security personnel can conduct business in a more professional manner with greater efficiency and improved control of visitors, vendors, and employees. The new facility contains state-of-the-art technologies and remote video surveillance and operates 24 hours a day, 7 days a week.

OSHA Train the Trainer

By providing OSHA Certified Training to upper and middle management and select hourly employees, Electric Boat Corporation, Quonset Point Facility

ity is aware of the various safety requirements of both industrial and maritime OSHA standards. Clear understanding of OSHA expectations provides an excellent foundation to continue eliminating lost work days due to injuries and providing a safe work environment.

Recently, Electric Boat Corporation, Quonset Point Facility (EBQP) administered the Occupational Safety and Health Administration's (OSHA's) Train the Trainer Program to all levels of management and select members of its Behavior Observation Awareness Team (BOAT). This type of management training is not surprising considering that safety is EBQP's number one priority. The company reflects its commitment to safety in goal-setting processes by establishing safety as the first performance metric it tracks and evaluates for managers and supervisors. Recognizing that more is needed to ensure continuous improvement, EBQP elevated the level of safety awareness at management levels throughout the facility.

EBQP recognized that managerial motivation alone does not improve safety. An appreciation by the workforce of management's commitment to safety is also essential. Even if the two conditions are present, a comprehensive understanding of safe work practices and the knowledge of how to create and maintain a safe work environment must exist to achieve continuous safety improvement. To fulfill these educational requirements, EBQP implemented an OSHA certified program which was facilitated by Keene State College. The program consists of information on general safety (both industrial and maritime standards), including electrical, personal protective equipment, OSHA compliance, record keeping, machine guarding, and utilizing OSHA standards. Employees were committed to a 32-hour class, segregated into blocks, ensuring the classes would not interfere with production and could accommodate absenteeism or travel. By educating the management team, each member is equipped with the necessary information to implement injury prevention and accident reduction plans. Armed with this knowledge, management can influence safety performance through new techniques. Incentives (e.g., free lunches, ice cream bars, and jackets) help promote safety throughout the workforce.

All supervisors, upper management, and members of BOAT attended the workshop. After completing the training, each person was certified to

train others and issue an OSHA certification card. Plans are in place to offer a 10-hour OSHA general industry safety course to all remaining employees, further fostering safety awareness. A three-day, new-hire orientation combines specific articles of this training to all employees. Early response on the program is very positive, and injuries have been significantly reduced throughout the facility.

Persons with Disabilities

Electric Boat Corporation, Quonset Point Facility provides janitorial work opportunities for persons with disabilities. The arrangement has been in place since 1998 and has been well received by all employees who know these workers by name and appreciate their dedication.

In 1998, representatives from the J. Arthur Trudeau Memorial Center contacted Electric Boat Corporation, Quonset Point Facility (EBQP) to advise the company of its available services. The J. Arthur Trudeau Memorial Center is located in Warwick, RI and is a private, non-profit organization that provides a wide variety of services to children and adults with disabilities. Since EBQP had already utilized the Trudeau Center's clients to cut and assemble non-flame retardant protective hoods for production workers, a respect for what they could accomplish already existed.

Based on the Trudeau Center's services, a contract was signed whereby 18 clients, accompanied by a Trudeau job coach, provide cleaning tasks such as window washing, waste collection, and sweeping and mopping, and one client was assigned to work in the cafeteria area. Currently, four clients are on-site daily and are well known to EBQP's workforce. Each of these clients has more than three years' experience working at EBQP, and one client was hired as the full-time dishwasher by the food service provider in the cafeteria. The Trudeau clients provide custodial service for the office areas, but do not work in the heavy manufacturing areas due to safety concerns.

The arrangement with the Trudeau Center allows EBQP to extend its employment opportunities to persons from the community who experience barriers to social and economic independence and may have been overlooked in the past. EBQP's workforce respects these clients and has adopted them as part of its family of employees.

State-of-the-Art Security Badge System

The new "Eye-on-Entry" security badge system offers Electric Boat Corporation, Quonset Point and Groton Facilities a state-of-the-art tool for controlling employee and visitor access. This system "raises the bar" on security badge systems with access control, efficient processing and production, and accountability and verification.

Electric Boat Corporation Quonset Point Facility (EBQP) began a major capital improvement of its security badge system after recognizing that its current badge system did not provide the efficiency, security, and full facility access control. Current employee and visitor badges were vulnerable to tampering or being transferred. The new system adds multi-function processing terminals to the current dual-function terminals. The dual-function terminals required badge swiping and did not control access to the facility at various points of entry. The multi-function processing terminals allow close-range scanning instead of swiping, full point-of-access discrimination, and wand scanning for multiple work areas.

These new features are part of EBQP's "Eye-on-Entry" system. This system produces higher quality employee and visitor badges, and offers a greater degree of control. Employee and visitor badges will display important information (e.g., facial photographs, color and bar coding, escort requirements, accessibility rights, expiration dates, and pre-entry qualifications) more prominently with close-range or wand scans, and immediately present additional details about representation, right of access, or other limitations.

Visit requests can be processed automatically through electronic correspondence signatures or the scanning of other identification (e.g., credit or ordinary business cards). Minimal data entry is required to revise the records. EBQP's "Eye-on-Entry" system will also be used for access to the Groton Facility, ensuring there is no redundant requirement for badges issued to employees or visitors.

Training Record System Database

Electric Boat Corporation, Quonset Point Facility's Training Record System Database makes it simple and easy for supervisors to plan and assign qualified workers to perform skilled tasks. It employs a user-friendly search and sort capability while indicating workers

whose qualifications are delinquent or will soon require training.

Electric Boat Corporation, Quonset Point Facility (EBQP) recognized the need for a database to effectively deal with the information pertaining to the training of its employees. Specifically, supervisors needed to track the qualifications and training needs of themselves and their employees. The Training Records System Database was created to track the training qualifications and training needs of each employee.

The Database was moved from a mainframe environment and is now available at the work area on desktop units, employing user-friendly search and sort capabilities. Supervisors can easily search the Database to plan and assign currently qualified workers to perform skilled tasks, and color codes are used to show worker records that are delinquent or will soon require training. EBQP's Training Record System Database also ensures that qualifications do not lapse, while combining personnel training needs in one convenient location.

Validation of Training

To understand the effectiveness and quality of its internal training, Electric Boat Corporation, Quonset Point Facility implemented a Validation of Training methodology to track and analyze training trends and results.

Because of the sophistication of its products and components for nuclear submarines, Electric Boat Corporation, Quonset Point Facility (EBQP) requires a substantial amount of training for its 1,800 employees. Training for submarine construction must be comprehensive, extensive, and require an effective method to measure the efficiency and quality of that training. EBQP realized it was not meeting customer and ISO-9000 requirements. Existing methods did not provide useful feedback on the effectiveness of training programs, and various evaluation tools did not reach their full potential nor provide useful metrics. It was also important to measure the students' ability to understand the course work, and the effectiveness of the trainers delivering the course work as well as the class evaluation of the course material. In 2002, EBQP implemented a Validation of Training methodology to track and analyze training trends and results.

EBQP currently uses several methods to understand training trends and results. Data is collected and entered into a local database, and results are tabulated and analyzed each quarter. Evaluation data is normalized and tracked over time. The metrics that are tracked include the percentage of those scheduled for training compared to those who attended, and whether trainees thought the training was important enough for people to attend. Class evaluations were plotted to compare the level of feedback from class to

class, and test averages were compared on a day-to-day basis.

EBQP's Validation of Training methodologies have been applied to approximately 60% of training activities with plans to expand the process to all training. With these benchmarks, EBQP can now better understand the current state of its training programs and methods, and gain insight into how and where to make improvements to realize the greatest benefits.

Appendix A

Table of Acronyms

ACRONYM	DEFINITION
AFC	Automated Frame and Cylinder
AT&A	Automated Time and Attendance
AWPSS	Automated Weld Process Statusing System
BOAT	Behavior Observation Awareness Team
BSWP	Build Sequence Work Package
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CCRI	Community College of Rhode Island
CCSM	Command and Control System Module
CI	Continuous Improvement
CIP	Continuous Improvement Program
CNC	Computer Numerical Control
DNC	Direct Numerical Control
DRP	Dispute Resolution Policy
EBC	Electric Boat Corporation
EBQP	Electric Boat Corporation, Quonset Point Facility
ECSA	Employee Community Services Association
EMS	Environmental Management System
ERS	Electronic Record System
EVS	Electronic Visualization Simulation
EWP	Electronic Work Package
GTAW	Gas Tungsten Arc Welding
GUI	Graphic User Interface
HVAC	Heating, Ventilation, and Air Conditioning
LWIR	Lost Workday Injury Rate
MCT	Multi-Cable Transit
MRP	Manufacturing Resource Planning
NCC	Navy Crane Center
NDT	Non-Destructive Testing
NNS	Newport News Shipbuilding
OSHA	Occupational Safety and Health Administration
PIP	Process Improvement Program
PPE	Personal Protective Equipment
QA	Quality Assurance

RIMES

Rhode Island Manufacturing Extension Service

SAF

Spherical Air Flask

SPC

Statistical Process Control

SWSS

Shipyards Weld Status System

VOC

Volatile Organic Compound

WST

Weapons Shipping Trunk

Appendix B

BMP Survey Team

Team Member	Activity	Function
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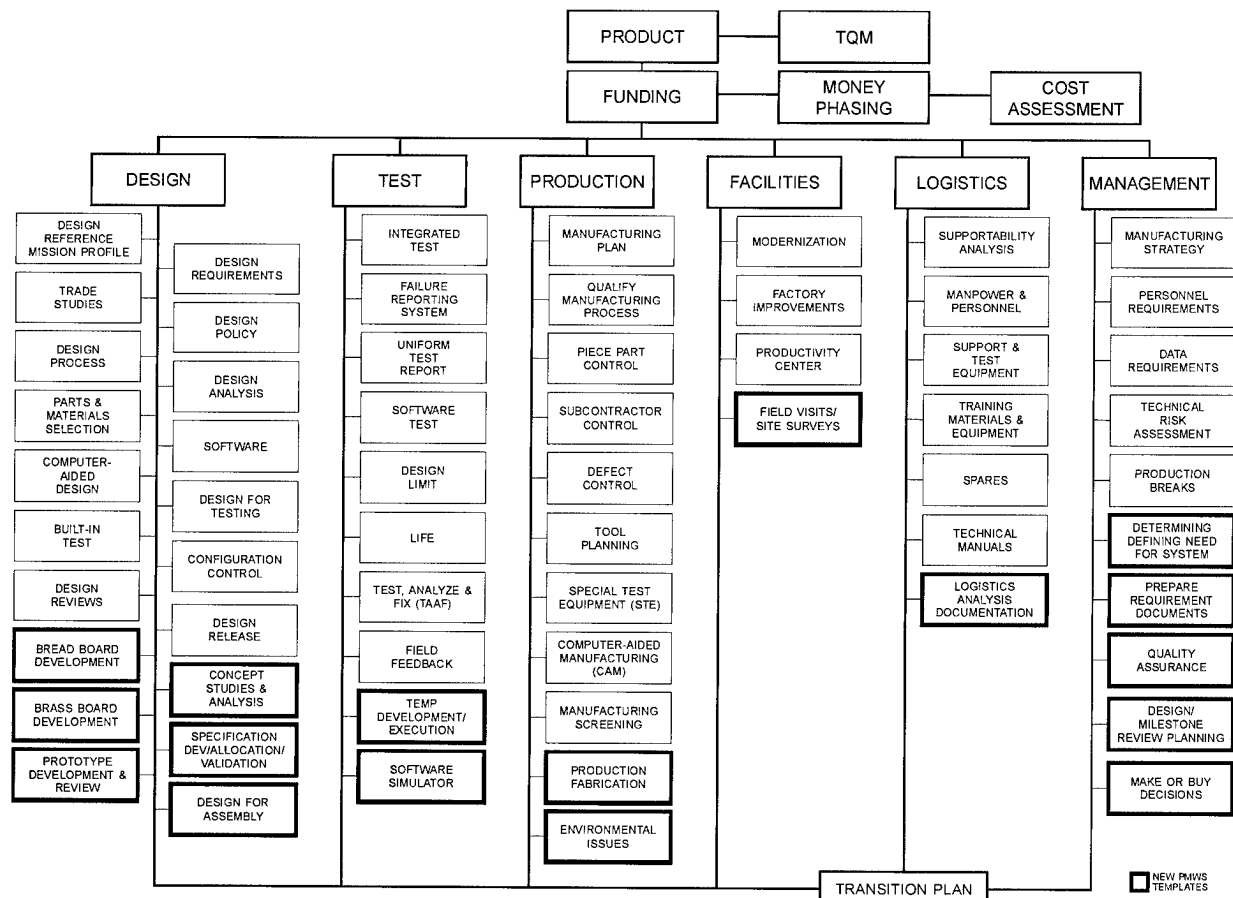
Appendix C

Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, Transition from Development to Production document. This publication defines the proper tools-or templates-that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing it as an industrial process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

“CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION”



Appendix D

The Program Manager's WorkStation

The Program Manager's WorkStation (PMWS) is an electronic suite of tools designed to provide timely acquisition and engineering information to the user. The main components of PMWS are KnowHow; the Technical Risk Identification and Mitigation System (TRIMS); and the BMP Database. These tools complement one another and provide users with the knowledge, insight, and experience to make informed decisions through all phases of product development, production, and beyond.

KnowHow provides knowledge as an electronic library of technical reference handbooks, guidelines, and acquisition publications which covers a variety of engineering topics including the DOD 5000 series. The electronic collection consists of expert systems and simple digital books. In expert systems, KnowHow prompts the user to answer a series of questions to determine where the user is within a program's development. Recommendations are provided based on the book being used. In simple digital books, KnowHow leads the user through the process via an electronic table of contents to determine which books in the library will be the most helpful. The program also features a fuzzy logic text search capability so users can locate specific information by typing in keywords. KnowHow can reduce document search times by up to 95%.

TRIMS provides insight as a knowledge based tool that manages technical risk rather than cost and schedule. Cost and schedule overruns are downstream indicators of technical problems. Programs generally have had process problems long before the technical problem is identified. To avoid

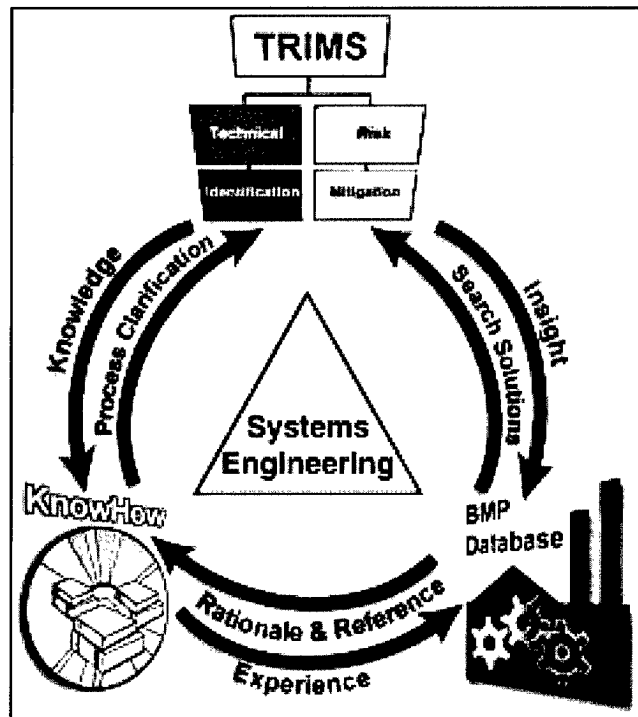
this progression, TRIMS operates as a process-oriented tool based on a solid Systems Engineering approach. Process analysis and monitoring provide the earliest possible indication of potential problems. Early identification provides the time necessary to apply corrective actions, thereby preventing problems and mitigating their impact.

TRIMS is extremely user-friendly and tailorable. This tool identifies areas of risk; tracks program goals and responsibilities; and can generate a variety of reports to meet the user's needs.

The **BMP Database** provides experience as a unique, one-of-a-kind resource. This database contains more than 2,500 best practices that have been verified and documented by an independent team of experts during BMP surveys. BMP publishes its findings in survey reports and provides the user with basic background, process descriptions, metrics and lessons

learned, and a Point of Contact for further information. The BMP Database features a searching capability so users can locate specific topics by typing in keywords. Users can either view the results on screen or print them as individual abstracts, a single report, or a series of reports. The database can also be downloaded, run on-line, or purchased on CD-ROM from the BMP Center of Excellence. The BMP Database continues to grow as new surveys are completed. Additionally, the database is reviewed every other year by a BMP core team of experts to ensure the information remains current.

For additional information on PMWS, please contact the Help Desk at (301) 403-8179, or visit the BMP web site at <http://www.bmpcoe.org>.



Appendix E

Best Manufacturing Practices Satellite Centers

There are currently ten Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP Program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; and train regional personnel in the use of BMP resources.

The ten BMP satellite centers include:

California

Chris Matzke

BMP Satellite Center Manager
Naval Surface Warfare Center, Corona Division
Code QA-21, P.O. Box 5000
Corona, CA 92878-5000
(909) 273-4992
FAX: (909) 273-4123
matzkecj@corona.navy.mil

District of Columbia

Geoffrey Gauthier

BMP Satellite Center Manager
U.S. Department of Commerce
Bureau of Industry & Security
14th Street & Constitution Avenue, NW
H3876
Washington, DC 20230
(202) 482-9105
FAX: (202) 482-5650
ggauthie@bis.doc.gov

Illinois

Robert Lindstrom

BMP Satellite Center Manager
Rock Valley College
3301 North Mulford Road
Rockford, IL 61114-5699
(815) 921-2073
FAX: (815) 654-4343
r.lindstrom@rvc.cc.il.us

Iowa

Bruce Coney

BMP Satellite Center Manager
Iowa Procurement Outreach Center
2273 Howe Hall, Suite 2617
Ames, IA 50011
(515) 294-4461
FAX: (515) 294-4483
bruce.coney@ciras.iastate.edu

Louisiana

Alley Butler

BMP Satellite Center Manager
Maritime Environmental Resources & Information
Center
Gulf Coast Region Maritime Technology Center
University of New Orleans
UAMTCE, Room 163-Station 122
5100 River Road
New Orleans, LA 70094-2706
(504) 458-6339
FAX: (504) 437-3880
alley.butler@gcrmtc.org

Ohio

Larry Brown

BMP Satellite Center Manager
Edison Welding Institute
1250 Arthur E. Adams Drive
Columbus, Ohio 43221-3585
(614) 688-5080
FAX: (614) 688-5001
larry_brown@ewi.org

Pennsylvania**John W. Lloyd**

BMP Satellite Center Manager
MANTEC, Inc.
P.O. Box 5046
York, PA 17405
(717) 843-5054
FAX: (717) 843-0087
lloydjw@mantec.org

South Carolina**Henry E. Watson**

BMP Satellite Center Manager
South Carolina Research Authority - Applied Research and Development Institute
100 Fluor Daniel
Clemson, SC 29634
(864) 656-6566
FAX: (843) 767-3367
watson@scra.org

Tennessee**Danny M. White**

BMP Satellite Center Manager
Oak Ridge Center for Manufacturing and Materials Science
BWXT Y-12, L.L.C.
P.O. Box 2009
Oak Ridge, TN 37831-8091
(865) 574-0822
FAX: (865) 574-2000
whitedm1@y12.doe.gov

Virginia**William Motley**

BMP Satellite Center Manager
DAU Program Director, Manufacturing Manager
Defense Acquisition University
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Ft. Belvoir, VA 22060-5565
(703) 805-3763
FAX: (703) 805-3721
bill.motley@dau.mil

Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Technology Program has established Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and the Navy industrial facilities and laboratories. These consortium-structured COEs serve as corporate residences of expertise in particular technological areas. The following list provides a description and point of contact for each COE.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and share best manufacturing and business practices being used throughout government, industry, and academia. The BMPCOE was established by the Office of Naval Research's BMP Program, the Department of Commerce, and the University of Maryland at College Park. By improving the use of existing technology, promoting the introduction of improved technologies, and providing non-competitive means to address common problems, the BMPCOE has become a significant factor to counter foreign competition.

Point of Contact:

Dr. Anne Marie T. SuPrise
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
Phone: (301) 403-8100
FAX: (301) 403-8180
E-mail: annemari@bmpcoe.org

Institute for Manufacturing and Sustainment Technologies

The Institute for Manufacturing and Sustainment Technologies (iMAST) is located at the Pennsylvania State University's Applied Research Laboratory. iMAST's primary objective is to address challenges relative to Navy and Marine Corps weapon system platforms in the areas of mechanical drive transmission technologies, materials processing technologies, laser processing technologies, advanced composites technologies, and repair technologies.

Point of Contact:

Mr. Robert Cook
Institute for Manufacturing and Sustainment Technologies
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
Phone: (814) 863-3880
FAX: (814) 863-1183
E-mail: rbc5@psu.edu

Composites Manufacturing Technology Center (Operated by South Carolina Research Authority)

The Composites Manufacturing Technology Center (CMTC) is a Center of Excellence for the Navy's Composites Manufacturing Technology Program. The South Carolina Research Authority (SCRA) operates the CMTC and The Composites Consortium (TCC) serves as the technology resource. The TCC has strong, in-depth knowledge and experience in composites manufacturing technology. The SCRA/CMTC provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and sub-contractors.

Point of Contact:

Mr. Henry Watson
Applied Research and Development Institute
Composites Manufacturing Technology Center
934-D Old Clemson Highway
Eagles Landing Professional Park
Seneca, SC 29672
Phone: (864) 656-6566
FAX: (864) 653-7434
E-mail: watson@scra.org

Electronics Manufacturing Productivity Facility (Operated by American Competitiveness Institute)

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of government, industry, and academic participants led by the American Competitiveness Institute under a Cooperative Agreement with the Navy.

Point of Contact:

Mr. Michael Frederickson
Electronics Manufacturing Productivity Facility
One International Plaza, Suite 600
Philadelphia, PA 19113
Phone: (610) 362-1200, ext. 215
FAX: (610) 362-1288
E-mail: mfrederickson@aciusa.org

Electro-Optics Center (Operated by The Pennsylvania State University's Applied Research Laboratory)

The Electro-Optics Center (EOC) is a national consortium of electro-optics industrial companies, universities, and government research centers that share their electro-optics expertise and capabilities through project teams focused on Navy requirements. Through its capability for national electronic communication and rapid reaction and response, the EOC can address issues of immediate concern to the Navy Systems Commands. The EOC is managed by the Pennsylvania State University's Applied Research Laboratory.

Point of Contact:

Dr. Karl Harris
Electro-Optics Center
West Hills Industrial Park
77 Glade Drive
Kittanning, PA 16201
Phone: (724) 545-9700
FAX: (724) 545-9797
E-mail: kharris@psu.edu

Navy Joining Center (Operated by Edison Welding Institute)

The Navy Joining Center (NJC) provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues. The NJC is operated by the Edison Welding Institute.

Point of Contact:

Mr. Harvey R. Castner
EWI/Navy Joining Center
1250 Arthur E. Adams Drive
Columbus, OH 43221-3585
Phone: (614) 688-5063
FAX: (614) 688-5001
E-mail: harvey_castner@ewi.org

National Center for Excellence in Metalworking Technology (Operated by Concurrent Technologies Corporation)

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. Operated by the Concurrent Technologies Corporation, the NCEMT helps the Navy and defense contractors improve manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:

Dr. Daniel L. Winterscheidt
National Center for Excellence in Metalworking Technology
c/o Concurrent Technologies Corporation
100 CTC Drive
Johnstown, PA 15904-1935
Phone: (814) 269-6840
FAX: (814) 269-2501
E-mail: winter@ctcgsc.com

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality, and safe energetics. The EMTC's focus is on technologies to reduce manufacturing costs, improve product quality and reliability, and develop environmentally benign manufacturing processes. The EMTC is located at the Indian Head Division of the Naval Surface Warfare Center.

Point of Contact:

Mr. John Brough

Naval Surface Warfare Center

Indian Head Division

101 Strauss Avenue

Building D326, Room 227

Indian Head, MD 20640-5035

Phone: (301) 744-4417

DSN: 354-4417

FAX: (301) 744-4187

E-mail: broughja@ih.navy.mil

Center for Naval Shipbuilding Technology

The Center for Naval Shipbuilding Technology (CNST) supports the Navy's ongoing effort to identify, develop and deploy in U.S. shipyards, advanced manufacturing technologies that will reduce the cost and time to build and repair Navy ships. CNST provides a focal point for developing and transferring new manufacturing processes and technologies; benefits that will accrue not only to the Navy,

but to industry as well. CNST is operated and managed by ATI in Charleston, South Carolina.

Point of Contact:

Mr. Ron Glover

Center for Naval Shipbuilding Technology

5300 International Blvd.

Charleston, SC 29418

Phone: (843)760-4606

FAX: (843)760-4098

E-mail: glover@aticorp.org

Gulf Coast Region Maritime Technology Center (Operated by University of New Orleans, College of Engineering)

The Gulf Coast Region Maritime Technology Center (GCRMTC) fosters competition in shipbuilding technology through cooperation with the U.S. Navy, representatives of the maritime industries, and various academic and private research centers throughout the country. Located at the University of New Orleans, the GCRMTC focuses on improving design and production technologies for shipbuilding, reducing material costs, reducing total ownership costs, providing education and training, and improving environmental engineering and management.

Point of Contact:

Mr. Frank Bordelon, New Orleans Site Director

Gulf Coast Region Maritime Technology Center

Research and Technology Park

CERM Building, Room 409

University of New Orleans

New Orleans, LA 70148-2200

Phone: (504) 280-5609

FAX: (504) 280-3898

E-mail: fbordelo@uno.edu

Appendix G

Completed Surveys

As of this publication, 135 surveys have been conducted and published by BMP at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMP web site. Requests for copies of recent survey reports or inquiries regarding BMP may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Anne Marie T. SuPrise, Ph.D., Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
annemari@bmpcoe.org

1985	Litton Guidance & Control Systems Division - Woodland Hills, CA
1986	Honeywell, Incorporated Undersea Systems Division - Hopkins, MN (now Alliant TechSystems, Inc.) Texas Instruments Defense Systems & Electronics Group - Lewisville, TX General Dynamics Pomona Division - Pomona, CA Harris Corporation Government Support Systems Division - Syosset, NY IBM Corporation Federal Systems Division - Owego, NY Control Data Corporation Government Systems Division - Minneapolis, MN
1987	Hughes Aircraft Company Radar Systems Group - Los Angeles, CA ITT Avionics Division - Clifton, NJ Rockwell International Corporation Collins Defense Communications - Cedar Rapids, IA UNISYS Computer Systems Division - St. Paul, MN
1988	Motorola Government Electronics Group - Scottsdale, AZ General Dynamics Fort Worth Division - Fort Worth, TX Texas Instruments Defense Systems & Electronics Group - Dallas, TX Hughes Aircraft Company Missile Systems Group - Tucson, AZ Bell Helicopter Textron, Inc. - Fort Worth, TX Litton Data Systems Division - Van Nuys, CA GTE C ³ Systems Sector - Needham Heights, MA
1989	McDonnell-Douglas Corporation McDonnell Aircraft Company - St. Louis, MO Northrop Corporation Aircraft Division - Hawthorne, CA Litton Applied Technology Division - San Jose, CA Litton Amecom Division - College Park, MD (now Northrop Grumman Electronic Systems Division) Standard Industries - LaMirada, CA (now SI Manufacturing) Engineered Circuit Research, Incorporated - Milpitas, CA Teledyne Industries Incorporated Electronics Division - Newbury Park, CA Lockheed Aeronautical Systems Company - Marietta, GA Lockheed Missile Systems Division - Sunnyvale, CA (now Lockheed Martin Missiles and Space) Westinghouse Electronic Systems Group - Baltimore, MD (now Northrop Grumman Corporation) General Electric Naval & Drive Turbine Systems - Fitchburg, MA Rockwell Autonetics Electronics Systems - Anaheim, CA (now Boeing North American A&MSD) TRICOR Systems, Incorporated - Elgin, IL
1990	Hughes Aircraft Company Ground Systems Group - Fullerton, CA TRW Military Electronics and Avionics Division - San Diego, CA MechTronics of Arizona, Inc. - Phoenix, AZ Boeing Aerospace & Electronics - Corinth, TX Technology Matrix Consortium - Traverse City, MI Textron Lycoming - Stratford, CT

1991	Resurvey of Litton Guidance & Control Systems Division - Woodland Hills, CA Norden Systems, Inc. - Norwalk, CT (now Northrop Grumman Norden Systems) Naval Avionics Center - Indianapolis, IN United Electric Controls - Watertown, MA Kurt Manufacturing Co. - Minneapolis, MN MagneTek Defense Systems - Anaheim, CA (now Power Paragon, Inc.) Raytheon Missile Systems Division - Andover, MA AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories - Greensboro, NC and Whippany, NJ Resurvey of Texas Instruments Defense Systems & Electronics Group - Lewisville, TX
1992	Tandem Computers - Cupertino, CA Charleston Naval Shipyard - Charleston, SC Conax Florida Corporation - St. Petersburg, FL Texas Instruments Semiconductor Group Military Products - Midland, TX Hewlett-Packard Palo Alto Fabrication Center - Palo Alto, CA Watervliet U.S. Army Arsenal - Watervliet, NY Digital Equipment Company Enclosures Business - Westfield, MA and Maynard, MA Computing Devices International - Minneapolis, MN (now General Dynamics Information Systems) (Resurvey of Control Data Corporation Government Systems Division) Naval Aviation Depot Naval Air Station - Pensacola, FL
1993	NASA Marshall Space Flight Center - Huntsville, AL Naval Aviation Depot Naval Air Station - Jacksonville, FL Department of Energy Oak Ridge Facilities (Operated by Martin Marietta Energy Systems, Inc.) - Oak Ridge, TN McDonnell Douglas Aerospace - Huntington Beach, CA (now Boeing Space Systems) Crane Division Naval Surface Warfare Center - Crane, IN and Louisville, KY Philadelphia Naval Shipyard - Philadelphia, PA R. J. Reynolds Tobacco Company - Winston-Salem, NC Crystal Gateway Marriott Hotel - Arlington, VA Hamilton Standard Electronic Manufacturing Facility - Farmington, CT (now Hamilton Sundstrand) Alpha Industries, Inc. - Methuen, MA
1994	Harris Semiconductor - Palm Bay, FL (now Intersil Corporation) United Defense, L.P. Ground Systems Division - San Jose, CA Naval Undersea Warfare Center Division Keyport - Keyport, WA Mason & Hanger - Silas Mason Co., Inc. - Middletown, IA Kaiser Electronics - San Jose, CA U.S. Army Combat Systems Test Activity - Aberdeen, MD (now Aberdeen Test Center) Stafford County Public Schools - Stafford County, VA
1995	Sandia National Laboratories - Albuquerque, NM Rockwell Collins Avionics & Communications Division - Cedar Rapids, IA (now Rockwell Collins, Inc.) (Resurvey of Rockwell International Corporation Collins Defense Communications) Lockheed Martin Electronics & Missiles - Orlando, FL McDonnell Douglas Aerospace (St. Louis) - St. Louis, MO (now Boeing Aircraft and Missiles) (Resurvey of McDonnell-Douglas Corporation McDonnell Aircraft Company) Dayton Parts, Inc. - Harrisburg, PA Wainwright Industries - St. Peters, MO Lockheed Martin Tactical Aircraft Systems - Fort Worth, TX (Resurvey of General Dynamics Fort Worth Division) Lockheed Martin Government Electronic Systems - Moorestown, NJ Sacramento Manufacturing and Services Division - Sacramento, CA JLG Industries, Inc. - McConnellsburg, PA
1996	City of Chattanooga - Chattanooga, TN Mason & Hanger Corporation - Pantex Plant - Amarillo, TX Nascote Industries, Inc. - Nashville, IL Weirton Steel Corporation - Weirton, WV NASA Kennedy Space Center - Cape Canaveral, FL Resurvey of Department of Energy, Oak Ridge Operations - Oak Ridge, TN

1997	Headquarters, U.S. Army Industrial Operations Command - Rock Island, IL (now Operational Support Command) SAE International and Performance Review Institute - Warrendale, PA Polaroid Corporation - Waltham, MA Cincinnati Milacron, Inc. - Cincinnati, OH Lawrence Livermore National Laboratory - Livermore, CA Sharretts Plating Company, Inc. - Emigsville, PA Thermacore, Inc. - Lancaster, PA Rock Island Arsenal - Rock Island, IL Northrop Grumman Corporation - El Segundo, CA (Resurvey of Northrop Corporation Aircraft Division) Letterkenny Army Depot - Chambersburg, PA Elizabethtown College - Elizabethtown, PA Tooele Army Depot - Tooele, UT
1998	United Electric Controls - Watertown, MA Strite Industries Limited - Cambridge, Ontario, Canada Northrop Grumman Corporation - El Segundo, CA Corpus Christi Army Depot - Corpus Christi, TX Anniston Army Depot - Anniston, AL Naval Air Warfare Center, Lakehurst - Lakehurst, NJ Sierra Army Depot - Herlong, CA ITT Industries Aerospace/Communications Division - Fort Wayne, IN Raytheon Missile Systems Company - Tucson, AZ Naval Aviation Depot North Island - San Diego, CA U.S.S. Carl Vinson (CVN-70) - Commander Naval Air Force, U.S. Pacific Fleet Tobyhanna Army Depot - Tobyhanna, PA
1999	Wilton Armetale - Mount Joy, PA Applied Research Laboratory, Pennsylvania State University - State College, PA Electric Boat Corporation, Quonset Point Facility - North Kingstown, RI Resurvey of NASA Marshall Space Flight Center - Huntsville, AL Orenda Turbines, Division of Magellan Aerospace Corporation - Mississauga, Ontario, Canada
2000	Northrop Grumman, Defensive Systems Division - Rolling Meadows, IL Crane Army Ammunition Activity - Crane, IN Naval Sea Logistics Center, Detachment Portsmouth - Portsmouth, NH Stryker Howmedica Osteonics - Allendale, NJ
2001	The Tri-Cities Tennessee/Virginia Region - Johnson City, TN General Dynamics Armament Systems - Burlington, VT (now General Dynamics Armament and Technical Products) Lockheed Martin Naval Electronics & Surveillance Systems-Surface Systems - Moorestown, NJ Frontier Electronic Systems - Stillwater, OK
2002	U.S. Coast Guard, Maintenance and Logistics Command-Atlantic - Norfolk, VA U.S. Coast Guard, Maintenance and Logistics Command-Pacific - Alameda, CA Directorate for Missiles and Surface Launchers (PEO TSC-M/L) - Arlington, VA General Tool Company - Cincinnati, OH
2003	University of New Orleans, College of Engineering - New Orleans, LA Bender Shipbuilding and Repair Company, Inc. - Mobile, AL In Tolerance Contract Manufacturing, - Cedar Rapids, IA Resurvey of Electric Boat Corporation, Quonset Point Facility - North Kingstown, RI